NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

INSTALLATION OF CENTRAL AIR CONDITIONING SYSTEM

Graduation Project
EE- 400

Student: Mohamed Elamin (20001017)

Supervisor: Asst. Prof. Dr.
Doğan Haktanır

Lefkoşa - 2006

CHAPTER ONE
INTRODUCTION

Air-conditioning design is a process of selecting the optimum system, subsystem, equipment, and components from various alternatives and preparing the drawings and specifications. This process is summarized in four phases: gather information, develop alternatives, evaluate alternatives, and sell the best solution. Design determines the basic operating characteristics of a system. After an air-conditioning system is designed and constructed, it is difficult and expensive to change its basic characteristics.

The foundation of a successful project is teamwork and coordination between designer, contractor, and operator and between mechanical engineer, electrical engineer, facility operator, architect, and structural engineer.

Air-conditioning is a process that simultaneously conditions air; distributes it combined with the outdoor air to the conditioned space; and at the same time controls and maintains the required space's temperature, humidity, air movement, air cleanliness, sound level, and pressure differential within predetermined limits for the health and comfort of the occupants, for product processing, or both.

Therefore, the goal of an air-conditioning system is to provide a healthy and comfortable indoor environment with acceptable indoor air quality, while being energy efficient and cost effective.

Theoretically, an air-conditioning system consists of equipment that provides an atmosphere that controls temperature, humidity, and purity at all times, regardless of weather conditions. In popular usage, however, the term air conditioning often is applied improperly to air cooling. Many so-called air-conditioning units consist merely of blower-equipped refrigerating units that provide only a flow of cool, filtered air.

Acceptable indoor air quality is defined as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

An air-conditioning consists of components and equipments arranged in sequential order to heat or cool, humidify or dehumidify, clean and purify, attenuate objectionable equipment noise, transport the conditioned outdoor air and recirculate air to the conditioned space, and control and maintain an indoor or enclosed environment at optimum energy use.

The use of electricity for heating purposes has long been favoured because it offers certain advantages over other sources of heat. There is an absence of fumes; heat is available immediately at any desired temperature; there is an ease of control; cleanliness is an important factor; and there is a reduction in the amount of labour required for operation as compared with other fuel systems. In recent years there has been an increase in the applications of electricity to provide heat, not only for domestic purposes, but also for industrial processes.

The multi-split systems have come of age in the last 5-10 years and are particularly popular because they require less outdoor plant space than conventional systems, are less disruptive to fit in existing buildings (particularly when occupied), are able to cool and heat through common pipe work and sometimes have inherent heat recovery.

These systems all use refrigerant as the cooling and heating medium rather than chilled water and hot water as is used in conventional hydraulic systems circulated by pumps.

Condensing units are used externally when cooling only is required and heat pumps are used externally when both cooling and heating are required.

The traditional split system is also known colloquially and more descriptively as a one to one split system, meaning one external condensing unit or heat pump is connected by refrigerant pipe work to one indoor cooling / cooling and heating unit.

The multi-split system uses one external unit which is connected to several indoor units. The multi-split system takes a number of different forms and it is essential the designer understands the limitations of each type of system.

One off external condensing unit is connected to several indoor units as is typical for a multi-split system. One of the indoor units is provided with temperature controller and acts as master and the other units act as slaves. All indoor units will therefore function as the master setting. Master and slave units are suitable for single areas, single rooms or even multiple rooms with very similar heat gains and losses. They are not suitable for individual areas which have different heat gain and loss characteristics because the master control will sense air temperature for one area room only and the areas will overcool or overheat.

The area, Onar Village, is situated on a skirt of the Kyrenia mountain range, about five minutes from the city centre. Its unique, 180-degree panoramic view overlooks the northern Mediterranean Sea and the ancient town of Kyrenia. It covers a total area of $1617m^2$ (29.32X5515).

Figure 1.1 Onar village

CHAPTER TWO
REVIEW OF LITERATURE

2.1 System equipments

2.1.1 Economizer Cycles

A number of options exist for heat recovery in conditioned spaces. The selection depends on site conditions and economics. The main categories are:

- Air-to-air heat recovery
- Direct evaporative cooling
- Combination (3-stage) cycles
- Outdoor air or ventilation cycle
- Indirect evaporative cooling
- Chiller "free" cooling

Air-to-air Heat Recovery - is often referred to as the exhaust air heat recovery cycle, since heat is recovered from the warm air exhausted from a building or process. Categories include:

- Process-to-process,
- Process-to-comfort,
- Comfort-to-comfort.

Within these categories there are different options. Making the selection is often dependent on the proximity of the exhaust to the supply air ducts. Consider these factors when making an evaluation:

- Energy costs
- The amount of useable waste
- The temperature of waste heat
- Other conservation options
- The effects on the HVAC system

- The effect on relative humidity
- The proximity of the supply and demand

Where exhaust and supply air ducts are not in close proximity, consider the glycol "run-around" loop system.

The rising costs of all forms of energy and the pressures to conserve water have focused attention on the issue of heat recovery: collecting heat that would otherwise be rejected in exhaust air or cooling towers and using it to augment the heating or cooling process. In an ideal heat recovery system, all components work year-round to recover the internal heat before adding external heat.

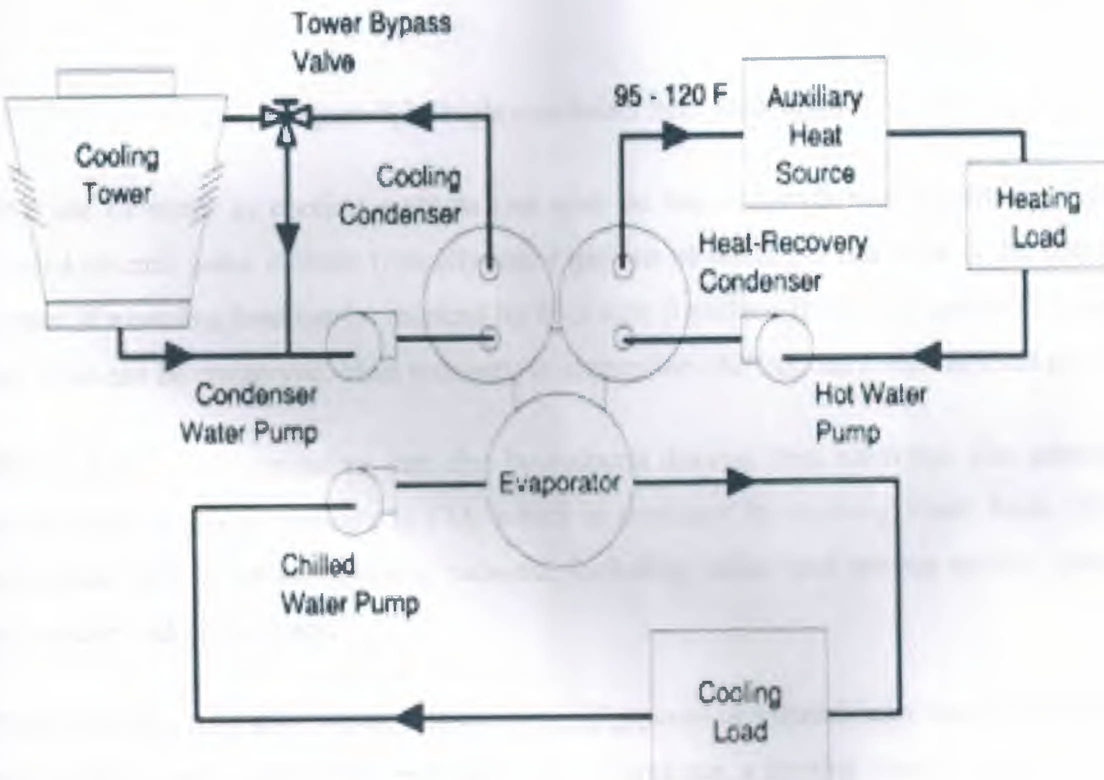


Figure 2.1 General system

The term for this concept is balanced heat recovery. However, few systems are this ideal. In any event, a significant amount of waste heat can often be economically recovered.

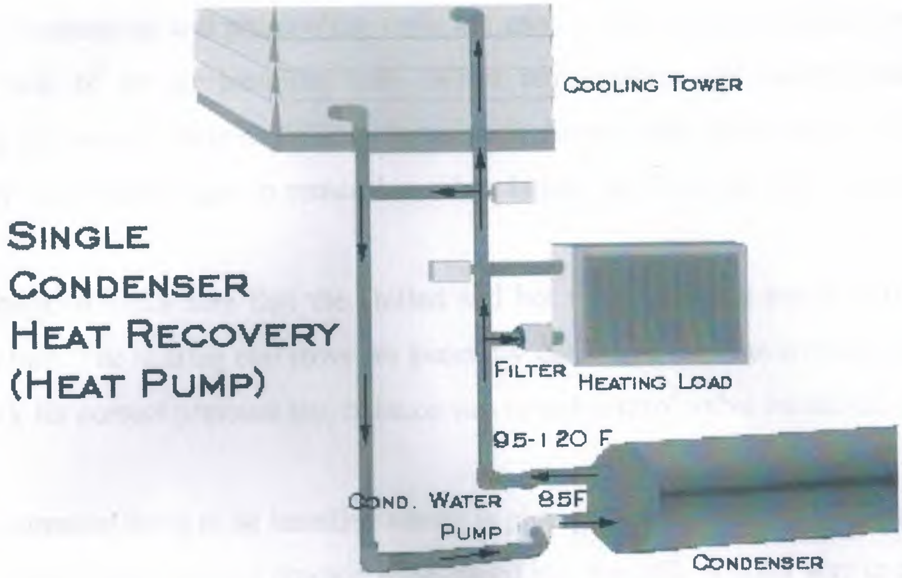


Figure 2.2 Single condenser heat recoveries

The use of water in cooling systems can also be reduced with heat recovery. Water-cooled electric water chillers typically use 4 gallons of water per ton-hour in the cooling tower. If a cooling load can be reduced by 83.3 tons (l million Btuh), 333 gallons of water per hour can be conserved. Heat recovery in absorption chillers can conserve even more.

Site and source air emissions can also be reduced through heat recovery. The principal contributor to global warning is CO_2 which is produced by burning fossil fuels. Other emissions will be proportionately reduced, including sulfur and nitrous oxides, carbon monoxide and particulates.

Other benefits may also occur. For example, if process or internal heat can be recovered and used, it could reduce the need for, or even eliminate, a cooling tower or other device used to reject previously unwanted or unused waste heat.

2.1.2 Coils

Coils can be used for many different applications such as: cooling, heating, pre-heating, pre-cooling, and re-heating. The three types of fluids used are: water, refrigerant, and steam. Preheating and pre-cooling coils are used to heat or cool outside air coming into the back of an air handling unit. When temperatures get below freezing the preheating coil would come on to keep water coils downstream from freezing. There are a few very important things to remember when balancing flow through a chilled water coil:

Always check to make sure that the chilled and hot water is being piped to the correct coil in the unit. The heating coil rows are generally much less than the cooling coil.

Also check for correct pressure tap, balance valve, and control valve locations.

The most common thing to be installed wrong is piping the coil backwards. This is where the supply and return lines get crossed when piped into the coil. A great way to check this is to remember the saying "Warmest Water hits the Warmest Air". This means that the warm air or return air should be hitting the warm water or return water first.

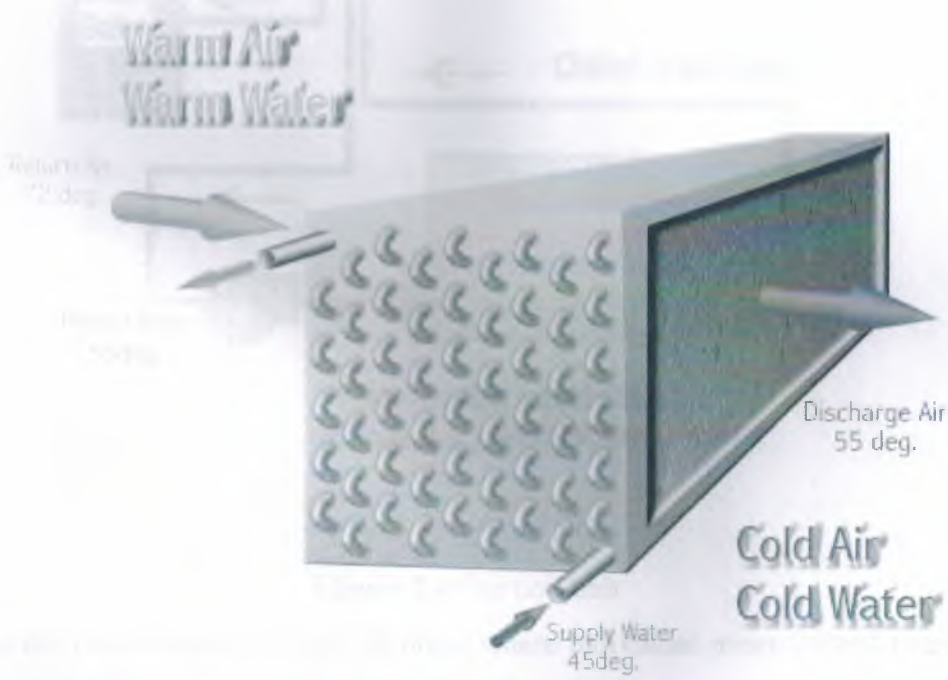


Figure 2.3 Coil

2.1.2.1 Fan Coil/Unit Ventilator Systems

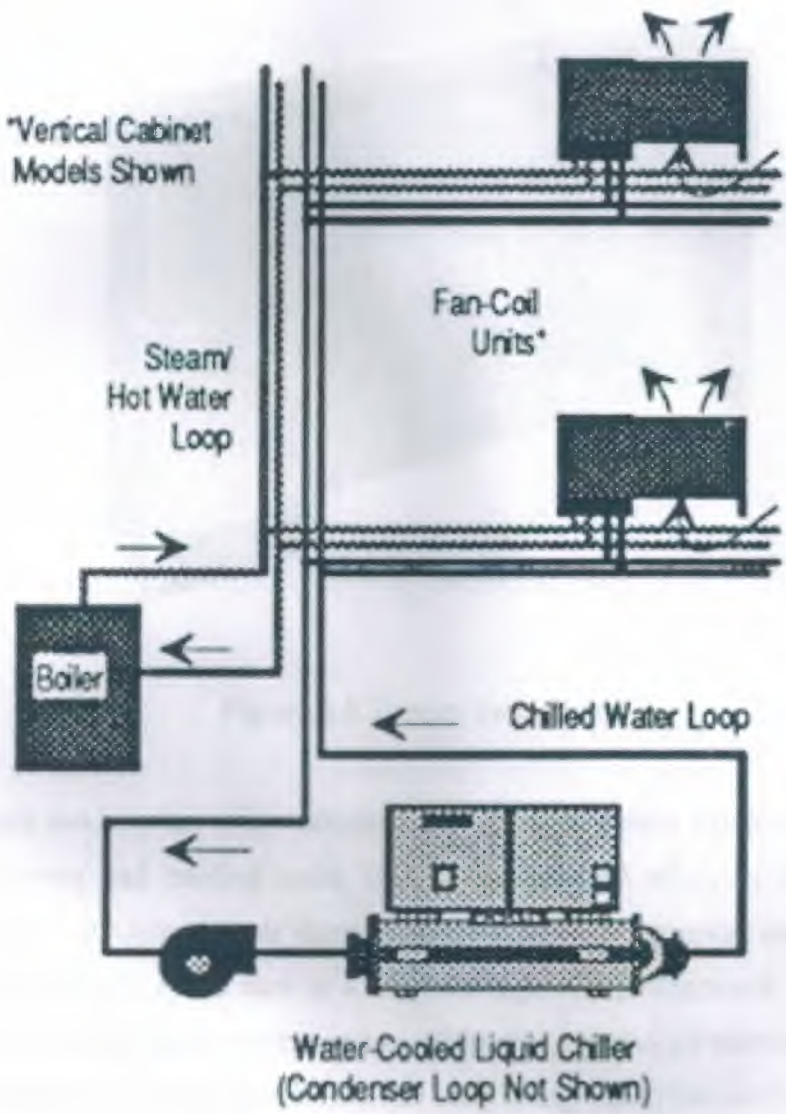


Figure 2.4 Fan coil unit

Fan coils are most commonly used in areas where individual room control is essential, such as hotels, private and public office buildings, hospitals and schools. Fan coils and unit ventilators are excellent examples of single-zone systems. These systems are available in horizontal ceiling mounted, concealed, or recessed vertical floor mounted arrangements. These systems are typically sized based on peak airflow, but the central refrigeration and heating sources are based on typical loads.

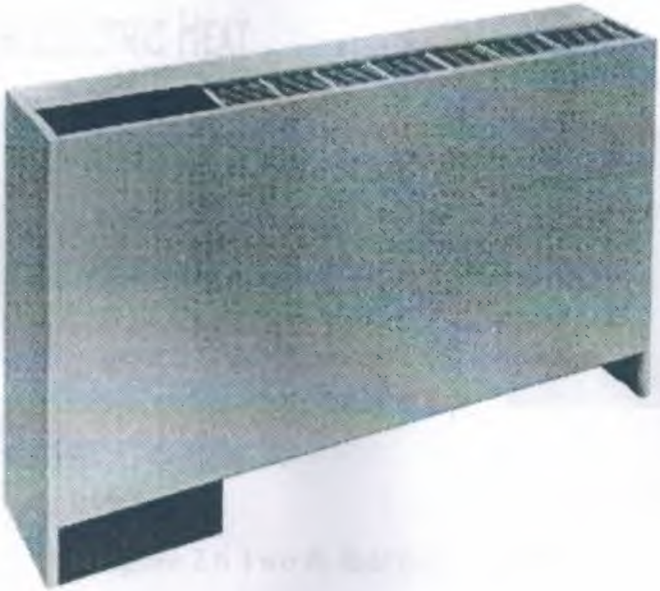


Figure 2.5 Type of fan coil unit

These systems use in-room units contained in a common casing where components such as a fan, heating and cooling coils, filters, controls and often, in the case of unit ventilators, the outside/return air damper are packaged. A common configuration uses low pressure, multiple speed fans in a blow-through coil arrangement. A chilled water cooling coil is typical, but direct expansion refrigerant systems are also used. The heating coil can be hot water, steam or electric. For coils using water, two or four-pipe systems are very common. Where wall penetrations are not acceptable, ventilation can be supplied by a separate system.

Fan Coil/Unit Ventilator Systems are:

- Two-Pipe system.
- Four-Pipe system.

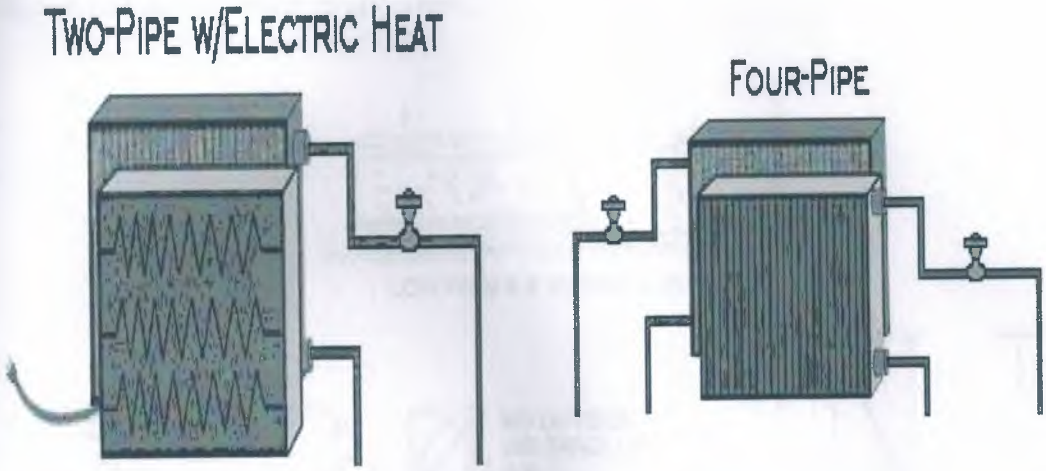


Figure 2.6 Two & four pipe systems

For two-pipe applications, the system designer must consider the change-over from cooling to heating duty. Multiple chillers and/or boilers may be required for multiple zones. Unit mounted controls utilize a pipe-mounted sensor to "tell" the unit whether it is heating or cooling, thereby opening or closing the closing valves accordingly.

Four-pipe systems utilize two independent coils, one for heating and one for cooling, Cooling and heating valves for controlling coil capacities are often factory installed with their controls hidden inside the cabinet , wall-mounted, or remotely mounted to prevent students or other occupants from tampering with them.

Two-pipe systems use a single coil for cooling or heating. A two-pipe system with intermediate season electric heating is a popular first-cost choice versus a four-pipe system. In the summer and intermediate seasons, the unit calls for cooling when the room temperature rises above the set point. If the room temperature drops too far below the set point, the cooling valve closes and the electric heat is energized.

The advantage of a two-pipe system with an electric heated fan coil tends to be recognized during the transition months (fall or spring) when cooling or heating can be required in the same day. The change-over is automatic with a system utilizing a thermostat that senses water temperature.

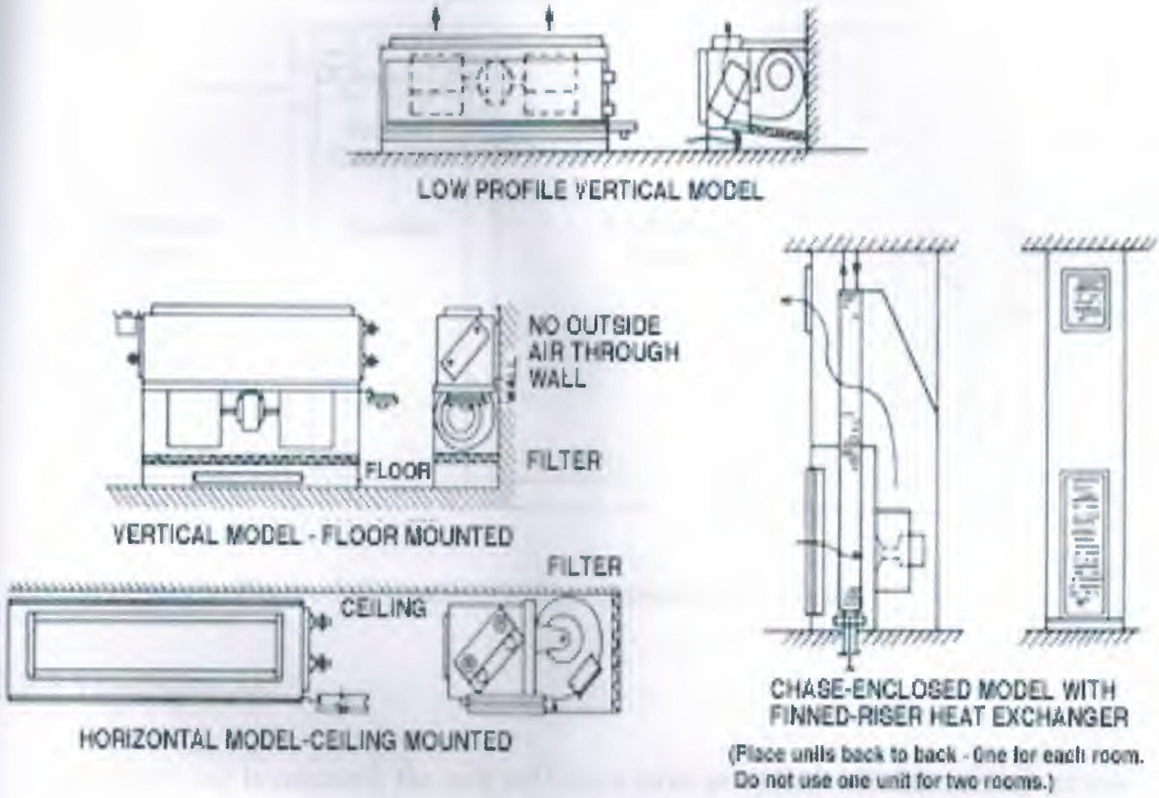


Figure 2.7 Typical fan-coil unit arrangements

2.1.2.2 Fan Coil/Unit Ventilator Systems - Application Considerations

Fan coils or unit ventilators are typically installed around the perimeter of a building, on walls, under windows or suspended in the ceilings. A mechanical equipment room on each floor is unnecessary. Perimeter setting provides easy access to outside air. However, in some cases, architecturally attractive grilles are used or outside air can be introduced through a central shaft. Perimeter setting also makes it easier to run coil piping and condensate drain connections to each unit.

Both unit ventilator and fan coil systems have filters and fan drive components that require periodic maintenance. Service and maintenance could interrupt occupants. Therefore, ease of access is important when specifying either of these units.

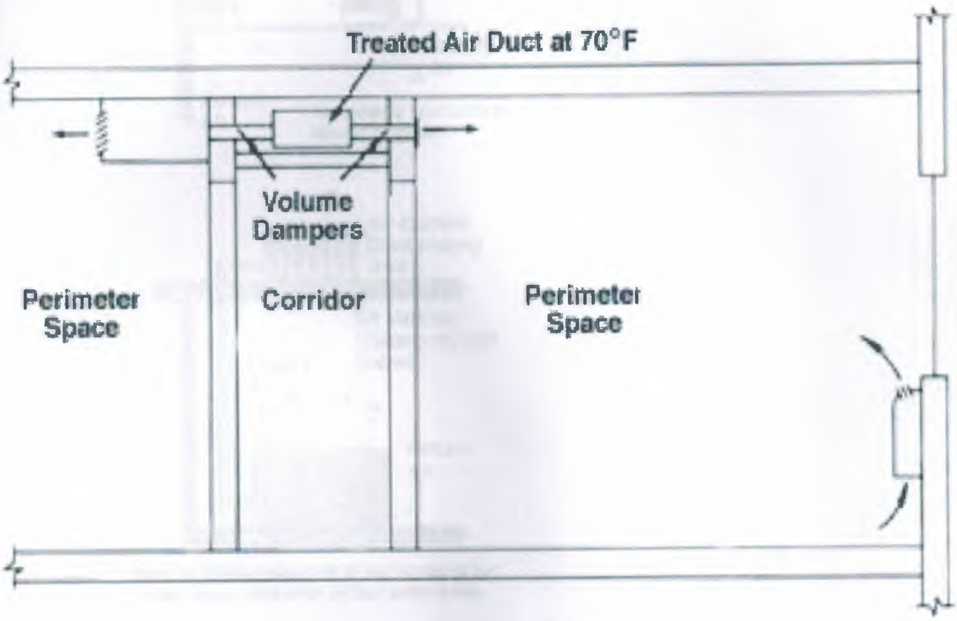


Figure 2.8 Ventilation form separate duct system

2.1.2.3 Ventilation Air

If outside air is required, the unit will often have an outside air damper that mixes outside air with return air inside the unit cabinet. This also enables an air economizer cycle where air is used for cooling purposes. Air intake grilles on a building's exterior provide a path for outside air to enter the unit.

2.1.2.4 Differences between Unit Ventilator and Fan Coil Systems

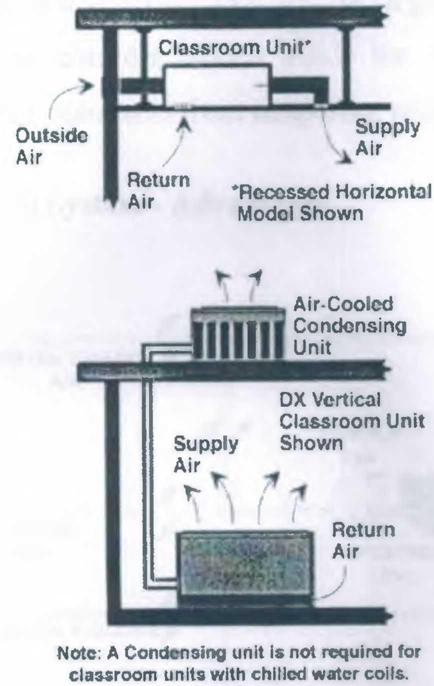


Figure2.9 Air conditioner

One main difference is in the unit cabinetry. Unit ventilators typically have heavier sheet metal cabinets which hold up better in the school environment. Classroom unit ventilators also have architectural advantages. School room units can have shelving or cabinetry built alongside the unit to help hide the comfort source.

Another difference is that unit ventilators are usually designed to deliver large amounts of outside air through exterior wall openings. Indoor air quality has become a major issue, especially in schools. ASHRAE Standards recommend ever larger percentages of outside air per student (i.e. 15 cfm per student). This results in larger ventilation loads. A classroom unit ventilator is specifically designed to handle these loads. In addition, utilizing chilled water and hot water coils allows for more stable control of coil discharge air temperature than with a direct expansion coil.

Heat gains can be as large as 7°F when a classroom suddenly fills with students. By taking in the outside air, unit ventilators can provide "free cooling" during cooler weather. A discharge air thermostat maintains a minimum leaving air temperature from the unit to prevent "dumping" of cold air onto students seated near the unit.

Unit ventilators are generally available in larger sizes than fan coils, and both unit types often have their controls hidden inside the cabinet or remotely mounted to prevent students or other occupants from tampering with them.

2.1.2.5 Fan Coil System - Advantages

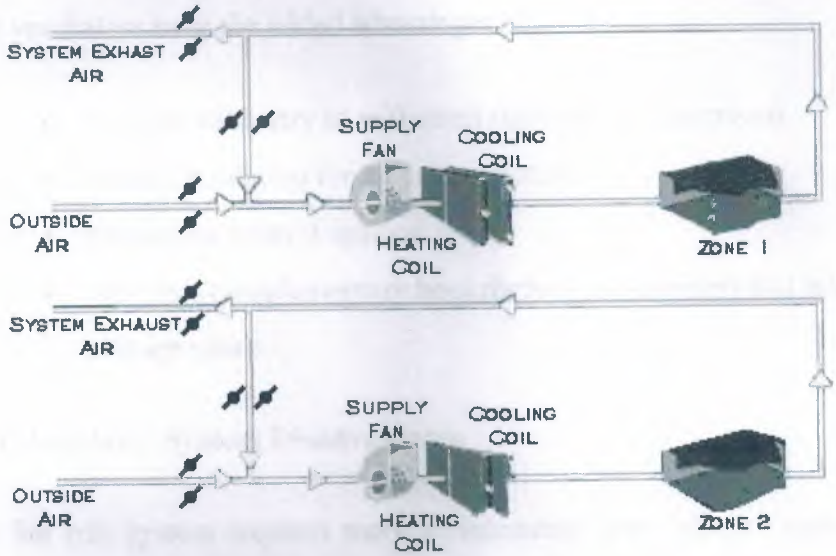


Figure 2.10 Fan coil unit ventilator

1. Central equipment may be sized smaller by taking advantage of building heating and cooling diversity.
2. The system requires only piping installation which takes up less space than all-air duct systems.
3. It is usually easier to install wire and water pipes than ducts making this a good choice for retrofit applications.
4. Unoccupied areas of the building may be isolated and shut down, saving money.
5. Zones can be individually controlled.
6. The system can accommodate up to 100% outside air capability.

2.1.2.6 Fan Coil System - Disadvantages

1. The Fan Coil System requires more maintenance than "all air" systems, and the maintenance work (such as servicing filters) is performed in occupied areas.
2. Condensate must be disposed of at each unit.
3. Interior zones may require separate ducts to deliver outside (ventilation) air.

2.1.2.7 Unit Ventilator System Advantages

Unit ventilators have the added advantages of:

- Heavier cabinetry to withstand rigors of the classroom
- Added insulation for quieter operation
- Numerous control options
- Optional complementary bookshelves and cabinets that add valuable storage space.

2.1.2.8 Unit Ventilator System Disadvantages

1. The fan coil system requires more maintenance than "all air" systems, and the maintenance work (such as servicing filters) is performed in occupied areas.
2. Condensate must be disposed of at each unit.
3. Interior zones may require separate ducts to deliver outside air.

Large exterior wall openings are required at each unit to accommodate 100% outside air capability.

2.1.3 The Condenser

The refrigerant is recovered by condensing it in a heat exchanger using air or water to reject the heat. Air cooled condensers are most common in smaller sizes, up to about 200 ton capacity. Technically, there is no upper limit on the size of an air cooled condenser, but operating cost issues usually dictate water cooled units for applications over about 100 tons.

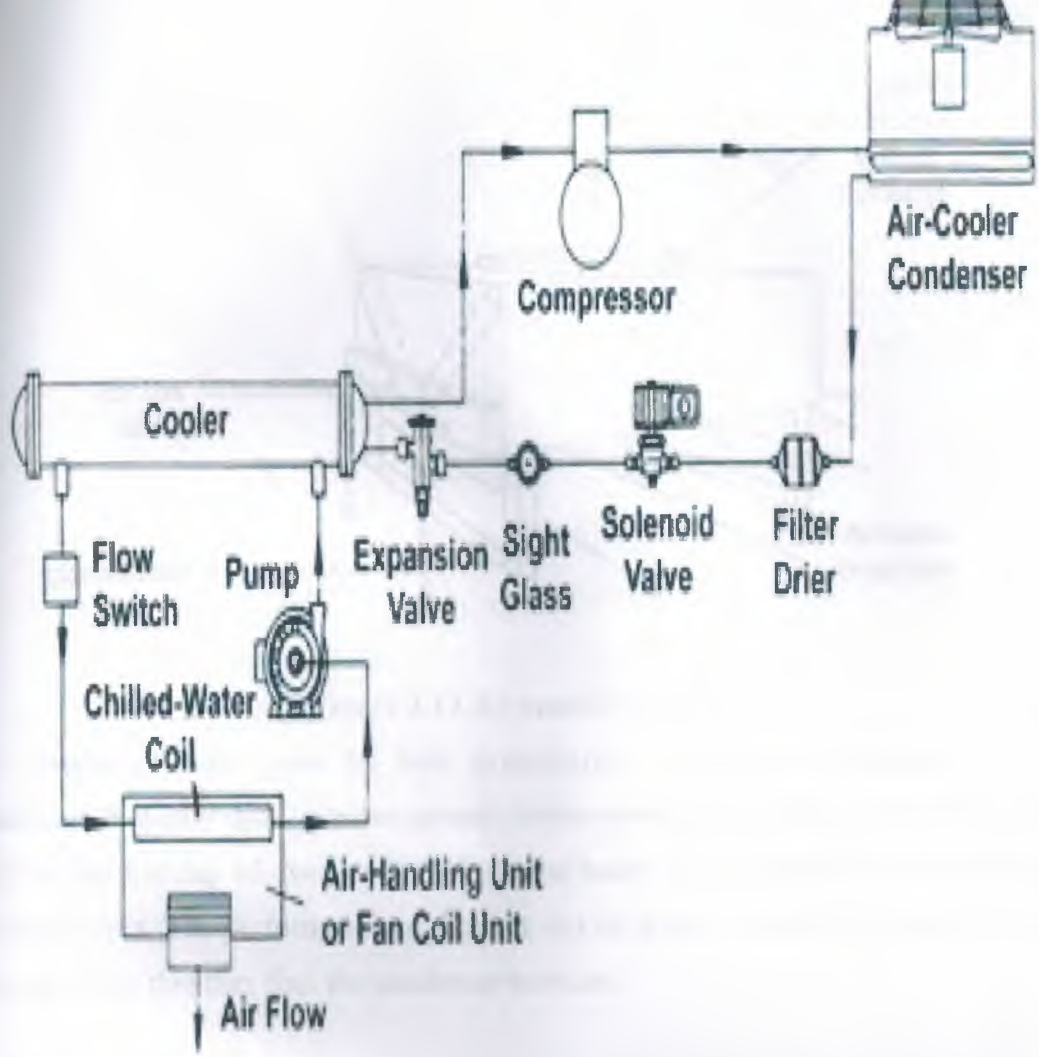


Figure 2.11 Condenser cycle

There are two water cooled designs:

- Cooling towers.
- Evaporative condensers.

Both work on the principal of cooling by evaporating water into a moving air stream. The effectiveness of this evaporative cooling process depends upon the wet bulb temperature of the air entering the unit, the volume of air flow and the efficiency of the air/water interface.

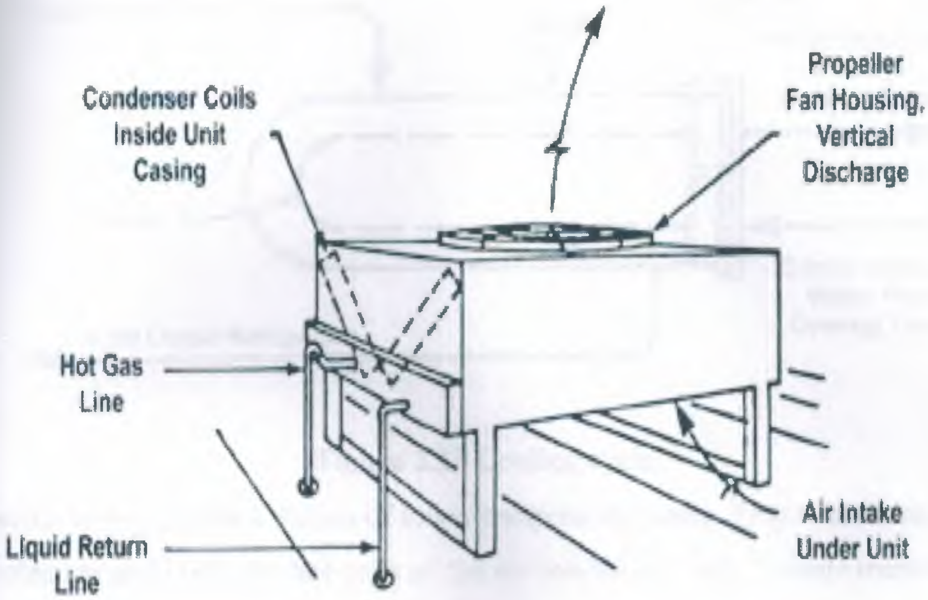


Figure 2.12 Air cooled condenser

The volume of water used by both evaporative condensers and cooling towers is significant. Not only does water evaporate just to reject the heat, but water must be added to avoid the buildup of dissolved solids in the basins of the evaporative condensers or cooling towers. The performance of the unit can be greatly reduced if these solids build up to the point that they foul the condenser surfaces.

2.1.3.1 Cooling Towers

Cooling towers are essentially large evaporative coolers where the cooled water is circulated to a remote shell and tube refrigerant condenser. Notice the cooling water is circulating through the tubes while refrigerant vapor condenses and gathers in the lower region of the heat exchanger. Notice also that this area "sub cools" the refrigerant below the temperature of condensation by bringing the coldest cooling tower water into this area of the condenser. The warmed cooling water is sprayed over a fill material in the tower. Some of it evaporates in the moving air stream. The evaporative process cools the remaining water.

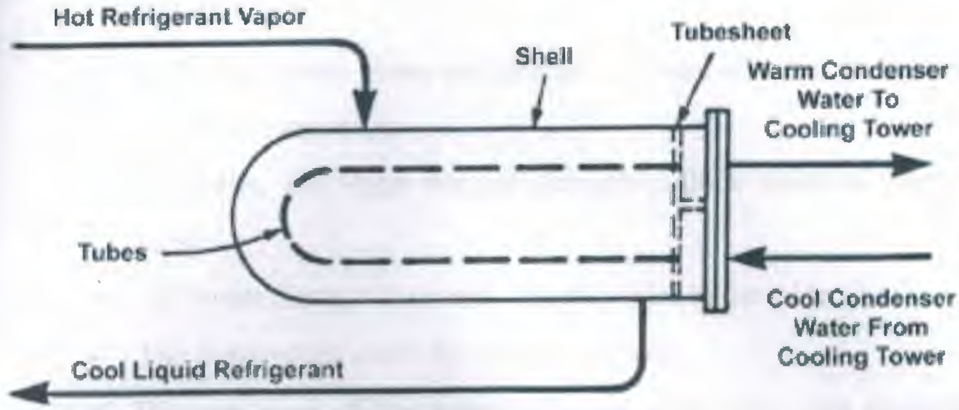


Figure 2.13 Cooling cycle

The cooling tower creates a stream of lower-temperature water. This water runs through a heat exchanger and cools the hot coils of the air conditioner unit. It costs more to buy the system initially, but the energy savings can be significant over time (especially in areas with low humidity), so the system pays for itself fairly quickly.

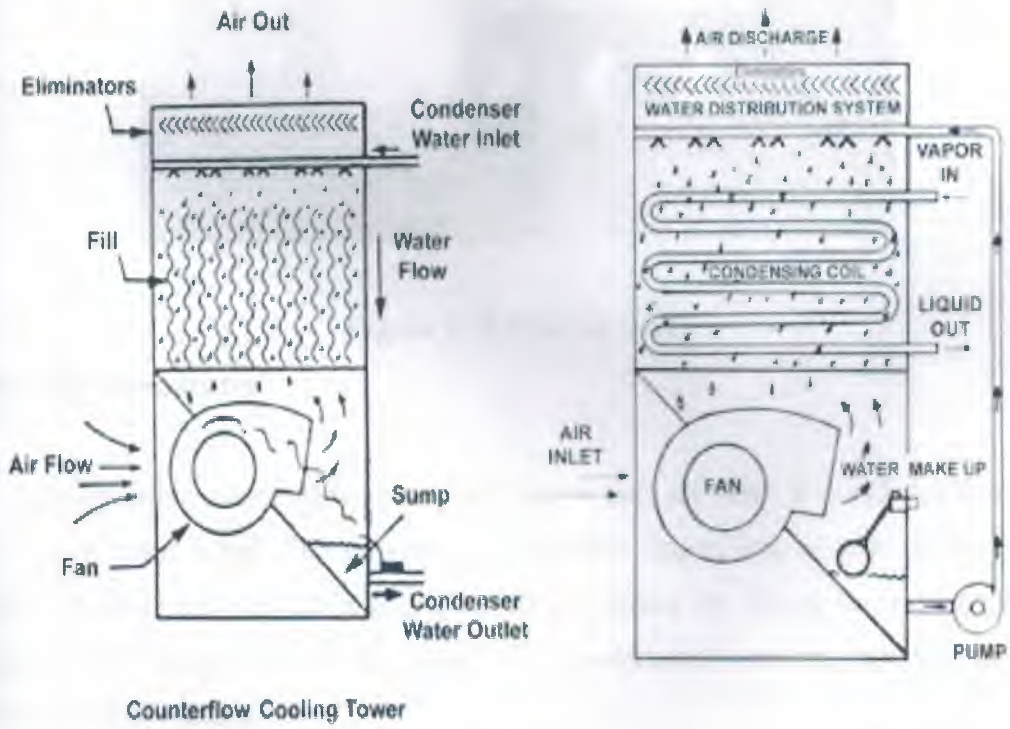


Figure 2.14 Counter-flow cooling tower

Cooling towers come in all shapes and sizes. They all work on the same principle:

- A cooling tower blows air through a stream of water so that some of the water evaporates.
- Generally, the water trickles through a thick sheet of open plastic mesh.
- Air blows through the mesh at right angles to the water flow.
- The evaporation cools the stream of water.
- Because some of the water is lost to evaporation, the cooling tower constantly adds water to the system to make up the difference.

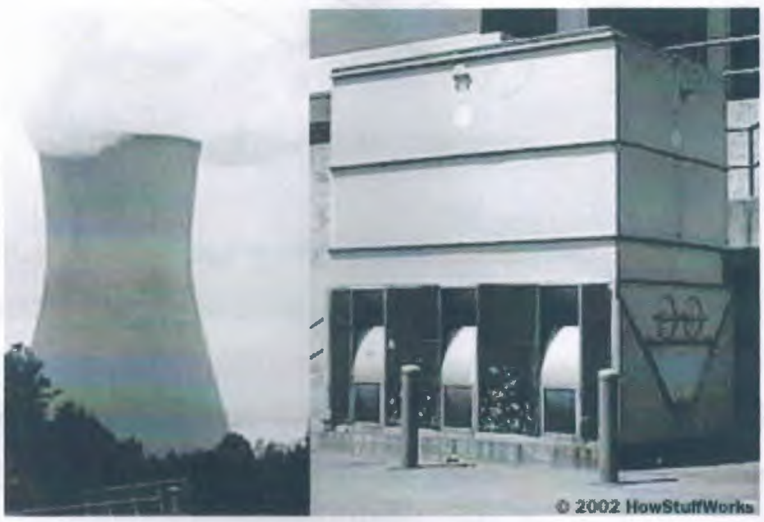


Figure 2.15 Cooling tower

2.1.3.2 The Evaporator

Evaporative condensers use water sprays and air flow to condense refrigerant vapors inside the tubes. The condensed refrigerant drains into a tank called a liquid receiver. Refrigerant sub cooling can be accomplished by piping the liquid from the receiver back through the water sump where additional cooling reduces the liquid temperature even further.

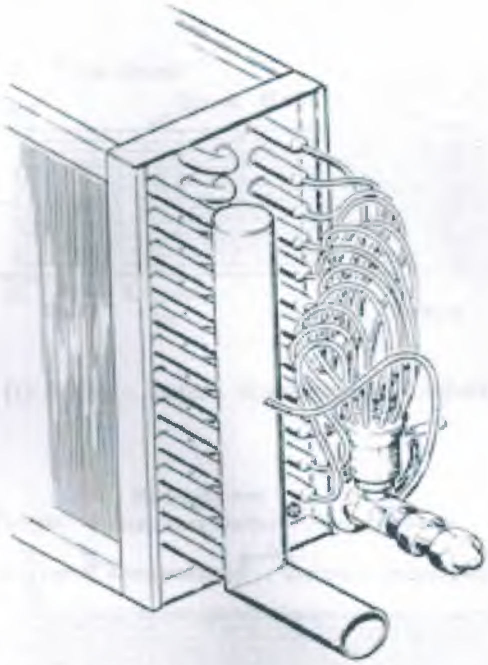


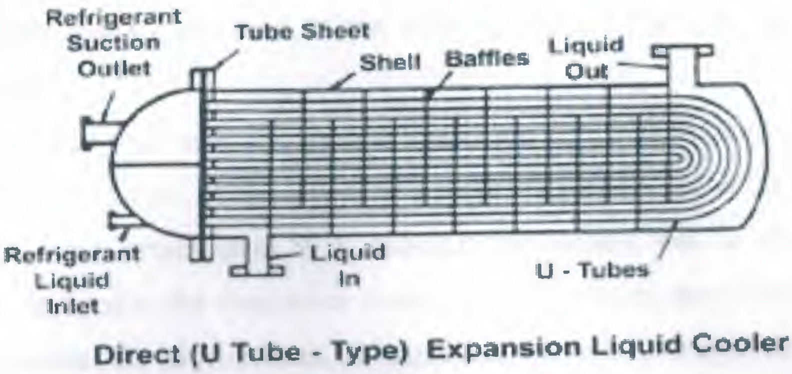
Figure 2.16 Evaporator

On the design day the evaporator typically cools either:

1. Air returning from the building space (or outside air) to 55 - 60°F
2. Water from about 54°F as it returns from building air handlers to 44°F.

In both cases the evaporator boils the selected refrigerant to provide this cooling. The pressure at which the refrigerant boils is exactly that which satisfies the energy balance of heat-in equals heat-out.

The refrigerant is circulated through numerous parallel paths. The pressure will drop as the refrigerant flows and evaporates along these paths. This in turn drops the temperature of the refrigerant as it evaporates. Consequently, properly designed direct expansion coils operate with the coldest refrigerant temperatures closest to the coil exit. However, the refrigerant temperature coming out of this coil is usually a little warmer than this to provide some level of superheat to be sure liquid refrigerant isn't leaving the coil and entering compressor (where it could cause mechanical failure in some designs).



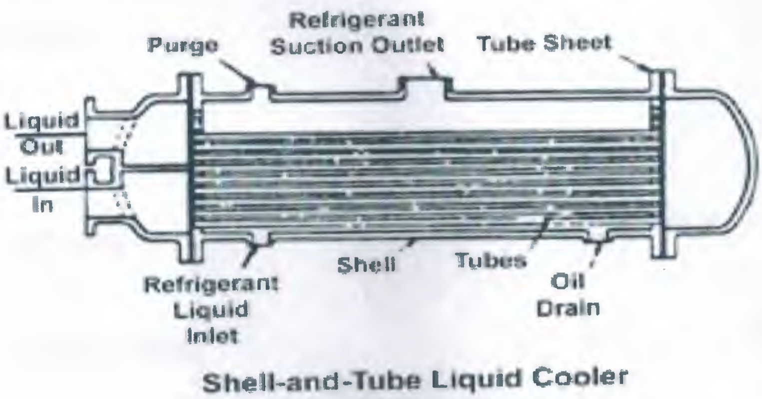


Figure 2.17 Liquid coolers

Shell and tube heat exchangers commonly have water circulated through the tubes and refrigerant boiling around the tubes. There are also designs where refrigerant flows within the tubes and water flows over the tubes. Baffles are normally used in this case to direct water flow in a serpentine fashion to optimize heat transfer. Almost all large chillers use shell and tube evaporators with water flowing through the tubes.

2.1.3.3 Vapor Compression Systems - Evaporator Control

In comfort cooling applications, actual cooling loads are seldom at full load conditions. Capacity control is achieved in finned coil evaporators that directly chill air by splitting the coil into independent sections. The principal reason is to permit coil sections to be activated and deactivated to better match coil cooling capacity with compressor loading. The combination of smaller coil sections controlled by correspondingly sized expansion valves improves valve performance and part load humidity control.

Capacity control in shell and tube evaporators is usually handled using the return water temperature. For example, if the full-load temperature range for chilled water is from 44°F to 54°F, water returning at 50°F indicates the cooling load is about 60%. Liquid refrigerant is metered to the evaporator to match the load using an orifice plate system or an expansion valve. On large chillers, the expansion valve is pilot operated.

2.1.4 Storage Tanks

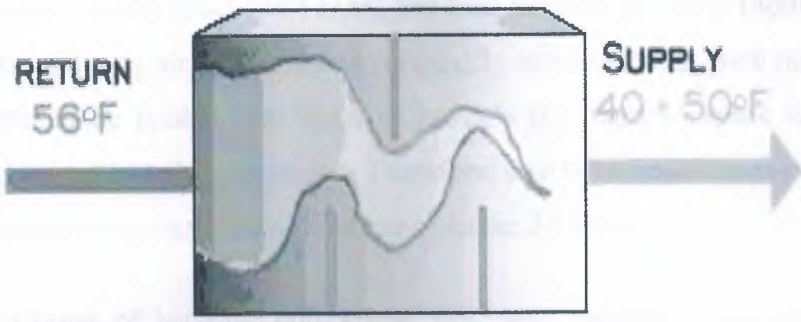


Figure 2.18 Storage tank

The simplest form of chilled water storage places one or more tanks in series in the de-coupler line. This is shown in this single baffled tank. Now, when the chillers produce more chilled water than the system requires, the excess is diverted to the series tank where it displaces the warmer water there. Likewise, when chilled water demand exceeds the quantity produced, chilled water is drawn from the storage tank by displacing it with warm return water.

A number of chilled water storage systems with designs similar to this have been installed and have proven to be fairly effective in reducing on-peak electrical demand. However, series tank design can cause the water to stratify or become stagnant. Stagnation is the tendency of water to shortcut its way through the tank, and renders large volumes of the tank ineffective for Btu storage. Furthermore, inter-compartmental mixing raises the tank's leaving water temperature as it empties. This reduces tank effectiveness during its final hours of discharge.

2.2 Cooling Capacity

Cooling systems are defined by:

1. The temperatures they can hold either in the space and/or the process or equipment.
2. The amount of heat they can remove at full capacity.

This heat removal is normally expressed in tons of cooling (or refrigeration) capacity. One ton of cooling equals precisely 12,000 Btu heat removal per hour (abbreviated Btuh) and comes from the way air handlers were originally rated -- that is, how many pounds of ice would have to be loaded into them to provide the required space cooling. When melting, ice gives up 144 Btu per pound. Therefore, one ton of cooling provides the same amount of cooling energy as melting one ton of ice in 24 hours.

For any given piece of installed equipment, this rated capacity is dependent upon the method used by the system to reject heat. For example, a cooling system rejecting heat to a dry fan-coil condenser will normally produce fewer tons of cooling on the design day than that same chiller mechanical system rejecting heat to a cooling tower. Put another way, any cooling system uses more power (or thermal input in the case of absorption chillers) to reject heat to a dry (air cooled) condensing system than to a wet (water cooled) condensing system.

This energy performance is defined by several measures: Coefficient of Performance (COP), kW/ton, Energy Efficiency Ratio (EER), and similar terms for thermally activated systems. The energy efficiency rating (EER) of an air conditioner is its BTU rating over its wattage. For example, if a 10,000-BTU air conditioner consumes 1,200 watts, its EER is 8.3 (10,000 BTU/1,200 watts). Obviously, you would like the EER to be as high as possible, but normally a higher EER is accompanied by a higher price

Most air conditioners have their capacity rated in British thermal units (BTU). Generally speaking, a BTU is the amount of heat required to raise the temperature of one pound (0.45 kg) of water 1 degree Fahrenheit (0.56 degrees Celsius). Specifically, 1 BTU equals 1,055 joules. In heating and cooling terms, 1 "ton" equals 12,000 BTU.

A typical window air conditioner might be rated at 10,000 BTU. For comparison, a typical 2,000-square-foot (185.8 m^2) house might have a 5-ton (60,000-BTU) air conditioning system, implying that you might need perhaps 30 BTU per square foot.

2.3 Chilled Water Temperature & Flow

Most large buildings use air handlers with chilled water coils. Historically, chilled water has been, supplied to these air handlers at ~ 44°F on the warmest days of the summer and would return to the chiller at about ~ 54 (i.e., 10°F warmer). Every ton of cooling delivered this way requires 2.4 gpm of water flow. Design professionals today have a multitude of alternatives available to them, including:

1. Increasing the difference between supply and return chilled water temperatures (called the chilled water range) to reduce chilled water pipe sizes and pumping power.
2. Increasing the coil surface area to permit higher chilled water supply temperatures,
3. And using lower temperature chilled water, perhaps in the 36 - 38°F range, to produce much colder supply air, thereby reducing air handler air flows, fan power, and duct sizing (which can even reduce building height).

These factors can impact energy use in complex ways. For example, distributing low temperature chilled water is often combined with increasing the chilled water range (e.g., supplying 38°F water and returning 58°F water). The chilled water flow is now only 1.2 gpm per ton, providing significant savings in chilled water distribution piping and pumps. However, producing 38°F water potentially requires more power and more expensive chiller designs. Certain building designs (such as churches, theaters, and operating room suites) can be "naturals" for ice storage. Similarly, chilled water at 40 - 42°F can sometimes achieve similar benefits.

All of these tradeoffs are complex and obviously fall within the domain of the design professional. Each design requires careful analysis, consideration of current and future building use, operating personnel qualifications, and the issues of initial investment and operating cost. This information is simply an explanation of some of the options available. Please refer to the specific cooling situation analyses elsewhere in this information system for further information.

2.3.1 Condenser Water Temperature & Flow

Chillers larger than about 100 tons usually have water circulating through the condenser. This water removes the heat from the chiller (the contribution due to the cooling as well as removing the heat from the motor, engine or absorber). Therefore a high efficiency electric chiller rated at 0.6 kW per ton rejects approximately 14,000 Btuh/ton of cooling. A high efficiency absorption chiller with a COP of 1.0 rejects about 24,000 Btuh/ton of cooling.

The circulating cooling tower water flow is determined primarily by the range in temperature. For example, with a high efficiency electric chiller, a 10°F range (e.g., supplying 85°F water to the chiller condenser and heating that water to 95°F), requires a condenser water flow of about 2.8 gpm per ton. With the same 10°F range, it would have to be about 4.8 gpm per ton for the high efficiency absorption chiller. This flow can be reduced by widening the range, but that would decrease the efficiency of the chiller itself.

The temperature of the water sent to the chiller condenser from the cooling tower is determined, largely by the ambient wet bulb temperature and the efficiency of the cooling tower (the amount of air drawn through the tower and the efficiency of air-water contact). Dry bulb temperature has only a minimal impact on cooling tower performance. The cooling tower is normally specified to meet the design wet bulb temperature in any geographic area -- commonly 75° to 78°F. The cooling tower manufacturer then designs the tower to produce 85°F water under this condition for the design heat rejection level and water flow. The temperature difference between the water sent to the condenser (i.e. coming off the cooling tower) and this wet bulb figure (say 78°F) is defined as the approach temperature 7°F (= 85 - 78).

This design day wet bulb condition occurs relatively few hours a year in most parts of the United States. During dryer times, the cooling tower can produce colder water than 85°F. And, most chillers will operate with reduced power input if this water temperature is reduced (down to a given limit as specified by the equipment manufacturer). This concept is called "floating the condenser" and holds the potential of conserving energy and reducing operating costs.

Selecting the condenser water parameters and cooling tower design is very complicated. Design of these systems requires experience, careful analysis, and consideration of initial investment and operating costs. The material presented here is simply an explanation of several design parameter opportunities. Please refer to the specific cooling design modules elsewhere in this information system for additional details.

2.4 Compressor Capacity and Performance

All compressors are rated in terms of how much flow they produce at a given ratio of outlet to inlet pressure (compression ratio). This flow is obviously a function of compressor size and operating speed (rpm), Compression ratio is defined by the discharge pressure divided by the suction pressure.

The limits of clearance volumes and valve pressure differentials force some of the compressor's flow volume capability to be lost as useful compression. This is referred to as volumetric efficiency. For example, at a compression ratio of 3 to 1, 82% of the volume of the compressor is useful. Therefore, if the refrigeration effect required 10 cfm of vapor flow from the evaporator, the compressor would have to produce 10/.82 or 12.2 cfm of flow.

2.5 System Economics

Most people make a purchase to solve a real or perceived problem. They use economic evaluations to justify their decision. With chillers, problems can range from inadequate capacity, chiller failure or high energy bills to the fear of CFC issues. In this section we will address the economics of chiller alternatives. A number of factors influence the costs of owning and operating large water chillers. These include:

1. Installed first cost, including any building modifications to accommodate one particular alternative over others.
2. Operating costs, including all the fuel, electric, and water costs (including the acquisition, treatment, and disposal of sewered water) to accommodate one alternative over others.
3. Maintenance costs, including preventive maintenance and the monitoring of refrigerants to minimize losses. Materials and supplies are also included here.
4. Insurance and Property Taxes.
5. Replacement Provisions, which takes into account the useful lives of the alternatives.
6. Financing, depreciation, and income taxes should also be considered. The money invested has a time value (interest) and there are usually tax consequences that affect decisions. It's usually a good idea to consult a tax accountant.
7. Method of evaluation which reflects individual owners needs the process of evaluating incremental first costs, along with the costs of owning and operating the various alternatives. These methods range from a simple payback calculation to much more sophisticated life cycle cost (or its equivalent net present value) analysis, or internal rate of return computations.

Each of these factors may vary according to the individual project. Typically, economic analyses are best performed using a computer model or program specifically designed for this purpose.

2.5.1 Critical Parameters

Critical parameters for fair comparisons call for a number of input assumptions. Some of the data may be readily available, some not so available. As many of the following factors as possible should be considered in conducting a proper evaluation:

1. Electric, steam and fuel rate schedules, including demand and energy charges segregated by applicable seasonal or time-of-use criteria and appropriate fuel adjustment charges.
2. Chiller type, size and full load efficiency: for electric chillers consider the kW per ton; for natural gas fueled check the Btu per ton-hour, or the steam pressure at the unit for steam chillers.
3. Consider the size cooling tower required rejecting the building's heat plus the work added to do the cooling that ends up in the chiller's condenser.
4. The chiller unit electric auxiliaries: for electric chillers these are included in the kW per ton; for non-electric chillers this kW per ton should include all the solution, refrigerant, jacket water, lube oil or other pumps (as applicable) and the control power.
5. The chiller system electric auxiliaries in kW per ton These include the condenser water pumps and the cooling tower fans plus any added fans or other power use's applicable to one type chiller but not another.
6. The costs (per 1,000 gallons) to acquire makeup water for the cooling tower, to chemically or otherwise treat this water, and to dispose of the tower overflow and the blow down needed to maintain an acceptable concentration of dissolved solids.
7. The projected annual operating hours of the chiller and the load profile it is designed to serve. For detailed analyses, the chiller's operating schedule including the utilities seasonal and on-peak time definitions must be taken into account. For less detail analyses, the concept of Equivalent Full Load Hours and Integrated Part Load Value can be used.

Several of these key parameters may require further definition. The issues of chiller efficiency, EFLH, IPLV, and APLV are addressed here.

2.5.2 Chiller Efficiency

Chiller operating efficiency is the major component in the annual energy cost. In the past energy was cheap and plentiful, and efficiency received little attention. Older chillers can be quite inefficient. In fact, some chiller replacements will payback quite quickly just due to significantly reduced operating cost at the higher efficiency of the new unit. For analysis purposes, chillers are typically compared on the basis of their ARI Standard Rating - Water cooled, using 44°F leaving chilled water and 85°F inlet condenser water.

All chillers require electric power to operate their auxiliaries (solution, refrigerant, and lube pumps, controls, and so on). These energy costs must be included in the economic comparison, as well as the cost of water required for the cooling tower. The chilled water pump consumption of electricity is common to all chillers, so this power input can be either included or omitted since it almost never affects the outcome of the analysis.

The typical BTU per ton heat rejection for electric chillers is calculated:

(kW/ton-hr x 3,413 Btuh/kW x 0.92) + 12,000 Btuh/ton

where the 0.92 factor makes an 8% allowance for the losses to ambient.

	Steam input	HHV input	Heat rejection	
	at Nom. psig	Btu/ton-hr	Btu/ton-hr	Temp.Diff.
Absorption				
1 stage steam	18 pph	22,000	29,000	15°F
2 stage steam	10 pph	12,200	22,300	10°F
Exhaust Gas Fired (EG)	Varies with EG temp.*		22,900	10°F
Direct Fired	NA	12,000	22,900	10°F
Natural Gas Engine Driven Compressor				
Reciprocating	NA	9,300	16,900	10°F
Rotary Screw	NA	8,600	16,500	10°F
Centrifugal	NA	7,760	16,300	10°F

Table 2.1 Heat-Driven Chiller

Tons Cooling = pph EG flow x (EG temp. - 375) / 40,950

The heat rejection values shown represent the approximate amount of heat that must be rejected to the atmosphere by the cooling tower. This value includes the 12,000 Btu per ton hour of cooling plus the Btu per ton-hour of energy input to the chiller, less an allowance for motor, drive, and radiation losses.

	Cooling Tower Fans	Condenser Water Pump*
Water-cooled Chiller	kW/ton	kW/ton
Reciprocating	.083	.057
Centrifugal	.079	.048
Absorption 1-stage steam	.138	.110
Absorption 2-stage (all models)	.113	.096
Natural Gas Engine	.087	.054

Table 2.2 Cooling Tower Fans & Pumps

These figures are based on efficiencies of 0.70 pumps and 0.90 motor. Condenser fan power is typically included in chiller rated input kW in packaged air-cooled units. If data is not available, estimate it at 0.128 kW/ton.

Chiller Type	**Gallons per ton**
Electric Chillers	4.0
Absorption 1-stage	8.0
Absorption 2-stage	6.2
Natural gas-driven	4.3

Table 2.3 Typical Chiller System Makeup Water Operating Cost Parameters

	Added kW/ton		
Nat. Gas-Engine Driven	Recip. Compr.	Screw Compr.	Centrifugal Compr.
	0.040	0.033	0.014
Absorption	1-Stage Steam	2-Stage Steam	Direct-Fired
	0.014	0.021	0.024

Table 2.4 Typical Chiller Unit Auxiliaries

2.5.3 Running Hours

The term Running Hours refers to the number of hours a year the chiller operates to meet the indoor design conditions. This usually refers to the number of hours cooling is required over the course of a year while the building is occupied or the enterprise is otherwise in use. The chiller auxiliaries plus the condenser water pump and tower fan will normally operate this number of hours. These hours vary by building type and geographical location.

2.5.4 Equivalent Full Load Hours

Equivalent Full Load Hours (EFLH): Even though a chiller is selected to supply the design load (100% or full load), it does not operate at full load for very many hours out of the year. For example many chillers operate for three quarters of each cooling season at 60% or less of design capacity. A chiller's part load efficiency has a significant effect on operating costs.

EFLH is defined as the annual ton-hours of cooling actually supplied divided by the supplying chiller's design capacity in tons. Using EFLH for analysis purposes is valid where the chiller plant has published continuous, performance values for energy input at all operating levels of output. Normally most centrifugal, screw, and absorption chillers fit this operating profile. However, reciprocating compressor chillers do not have this continuous performance characteristic, due to their step capacity operation and lower efficiency at part load. Therefore, their EFLH must be calculated using a more detailed procedure.

The load calculations for most buildings are performed using a personal computer. These calculations normally establish the running hours per year and enable the designer to estimate a building load profile. A sample annual load profile might look like this:

Annual Load Profile Percent load	**Percent running Hrs**
90% to 100%	2%
81% to 90%	3
71% to 80%	5
61% to 70%	15
51% to 60%	30
41% to 50%	20
31% to 40%	15
21% to 30%	5
11% to 20%	2
0 to 10%	100%

Table 2.5 Equivalent Full Load Hours

The expected EFLH can be projected using a buildings estimated load profile and total annual running hours. For example, using this load profile and an assumed 2,300 running hours, the EFLH can be calculated to be 1,277. If this chiller had a design capacity of 500 tons, it would deliver an estimated 638,500 ton-hrs of cooling (500 tons x 1,277 Equivalent Full Load Hours). PC-based energy analysis tools, including EPRI's COMTECH and APOGEE's chiller screening program, can perform this type of analysis very handily.

2.5.5 Operating Hours and EFLH

Chillers do not normally operate every hour of the year, and may not always operate when the building is occupied. There are days when outside air alone can supply the necessary cooling, and most chillers will require some periodic maintenance during the year even when the chiller could be running (where cooling would be supplied by other equipment during this period). For example, office buildings in the northern climates might call for a chiller to operate 1,000 hours a year while chillers in buildings along the Gulf Coast probably operate more than half the time the building is open. In very humid areas, chillers may have to operate even when the building is unoccupied just to maintain humidity levels. On the other hand, hospital operating rooms often require chiller operation every month of the year (although not necessarily every day). Obviously then, a chiller does not always operate at full load. If the chiller were to meet the annual cooling load by operating only at full load and then cycling off, it would end up operating fewer annual hours. These are defined as Effective Full Load Hours (EFLH) and typically make up about half of the annual operating hours. Therefore, a building that might operate a chiller for 2000 hours in colder climates for general space conditioning should typically expect about 1000 EFLH for that chiller.

CHAPTER THREE
METHODOLOGY

3.1 Design Considerations

The goal of an air-conditioning system is to provide a healthy, comfortable, manufactured indoor environment at acceptable indoor air quality, keeping the system energy efficient. Various occupancies have their own requirements for their indoor environment.

The term air-conditioning is used to describe systems ranging from simple ventilator fans to elaborate apparatus capable of providing an internal atmosphere with air filtered, humidified or de-humidified, heated or cooled, and controlled to accurate limits in each respect. In general, full air-conditioning techniques are found more in industrial and large commercial premises than in domestic premises where the provision is usually a small ventilating unit mounted in a kitchen window pane to extract cooking fumes and heat. With a ducted-air system of heating, the fan motor installed in a house can usually be run during the summer months (with the heating system closed down) to assist in the circulation of air throughout the house and so offer comfortable conditions when the external temperature tends to be high.

There are two main ways in which air-conditioning may be applied. First there is the small unit air conditioner, which consists of a small box containing a refrigerating compressor with cooling coil, a fan, a simple filter and sometimes a heater battery for use in the winter months. Then there is the centralised air-conditioning system which consists of a much larger and more elaborate set of air-treatment equipment installed in a plant chamber from which systems of ducting lead to and from the various parts of the building being served.

Small unit conditioners are common for cooling the rooms of buildings erected before air-conditioning was little more than a motorized fan mounted on the ceiling. They can be readily installed in windows without much structural upheaval.

For industtial applications in this country, the centralized system is common; its main function is to provide special atmospheric conditions of cleanliness, humidity or temperature to ensure uniformity of manufacture.

The common domestic ventilating fan is most often mounted in a window pane, though wall mounted units are also available. The size of fan unit must be correct for a particular application, and is based both on the size of the room and the rate of air change required. This latter factor depends on the situation. A living room requires a recommended minimum of five air changes per hour; a bathroom requires ten; and a boiler house requires twenty-five. The capacity of a ventilating unit is expressed in the number of cubic meters of air per hour moved. This figure is obtained by multiplying the volume of the room by the recommended number of air changes per hour.

Ventilator units can be used to extract air from a room (air removal) or to supply air to it. Many units are provided with reversible control and speed variation; some have automatic shutters which prevent back-draught through the unit when it is not operating. To be effective, these units should be positioned correctly so that cross ventilation is available. Also the units should move the air in every part of a room and particularly where there is a likelihood of stagnant air pockets being unaffected by the unit.

Clean air is generally provided by air filters, some of which are of the electrostatic type which operate on the principle of charging impurities in the air so that they collect on oppositely-charged metal plates in the filter unit.

The basic considerations to select an air-conditioning system include:

1. The selection of an air-conditioning system must satisfy the required space temperature, relative humidity, air cleanliness, sound level, and pressurization. For a Class 100 clean room, a single zone CV clean room system is always selected. A four-pipe fan-coil space conditioning system is usually considered suitable for guest rooms in hotels for operative convenience, better privacy, and a guaranteed outdoor ventilation air system. A concert hall needs a very quiet single-zone VAV central system for its main hall and balcony.

2. The size of the project has a considerable influence on the selection. For a small-size residential air-conditioning system, a single-zone constant volume packaged system is often the first choice.
3. Energy-efficient measures are specified by local codes. Comparison of alternatives by annual energy-use computer programs for medium and large projects is often necessary. Selection of energy source includes electricity or gas, and also using electrical energy at off-peak hours, like thermal storage systems is important to achieve minimum energy cost. For a building whose sound level requirement is not critical and conditioned space is comprised of both perimeter and interior zones, a WSHP system incorporating heat recovery is especially suitable for energy saving.
4. First cost or investment is another critical factor that often determines the selection.
5. Selection of an air-conditioning system is the result of synthetically assessment. It is difficult to combine the effect of comfort, reliability, safety, and cost. Experience and detailed computer program comparisons are both important.

The selection procedure usually begins whether an individual, space conditioning, packaged, central system, or CV, VAV, VAV reheat, fan-powered VAV, dual-duct VAV, or thermal storage system is selected.

Then the air, refrigeration, heating, and control subsystems will be determined. After that, choose the option, the feature, the construction, etc. in each subsystem

SYSTEMS(1)

Building	A	B	C	D	E(2)	F(3)	G	H	I(3)
Administration	X	X	X	X	X	X	X	X	X
Apt. Houses	-	-	X	-	-	X	X	X	
Auditoriums	X	X	X	X	-	X	-	X	X
Bachelor Quarters	X	X	X	X	X	X	X	X	X
Bakeries	X	X	X	X	-	-	-	X	X
chapels	X	X	X	X	-	X	X	X	X
Communications	X	X	X	X	-	X	X	X	X
Family Housing	X	-	X	-	-	X	X	X	X
Gymnasiums	X	-	-	-	-	-	-	-	X
Hangar	-	-	-	-	-	X	X	-	X
Hospitals	X	X	X	X	-	X	X	X	X
Laundries	X	X	X	X	-	-	-	X	X
Schools	X	X	X	X	-	X	X	X	X
Shops	X	X	X	X	-	X	-	-	X
Theaters	X	X	X	X	-	X	-	-	X
Transmitters	X	X	X	X	-	X	-	-	X
Warehouses	X	-	X	-	-	-	-	-	X

Table 3.1 Recommended Air conditioning Systems for Various Buildings

NOTES:

1. System Types:
   - A. single Duct System
   - B. Dual Duct System
   - C. Multi-zone System
   - D. Variable Air Volume System
   - E. Perimeter Zone Air system
   - F. Fan Coil System
   - G. Induction System
   - H. Heat Pump System
   - I. Evaporated Cooling System
2. Depends on building configuration
3. Depends on local weather conditions

Central systems use chilled and hot water that comes from the central plant to cool and heat the air in the air-handling units (AHUs). Central systems are built-up systems. The most clean, most quiet thermal storage systems, and the systems which offer the most sophisticated features, are always central systems.

3.2 Load Calculation Methodology

Before calculating heat loads we may go through some expressions like Space, Room, Zone, Load Profile, Peak Load, and Block Load.

Space indicates a volume or a site without partitions, or a partitioned room or a group of rooms. A room is an enclosed or partitioned space that is considered as a single load. An air-conditioned room does not always have an individual zone control system. A zone is a space of a single room or group of rooms having similar loads and operating characteristics. An air-conditioned zone is always installed with an individual control system. A typical floor in a building may be treated as a single zone space, or a multi zone space of perimeter, interior, east, west, south, and north... zones.

A load profile shows the variation of space, zone, floor, or building load in a certain time period, such as a 24-hr day-and-night cycle. In a load profile, load is always plotted against time. The load profile depends on the outdoor climate as well as the space operating characteristics.

Peak load is the maximum cooling load in a load profile. Block load is the sum of the zone loads and floor loads at a specific time. The sum of the zone peak loads in a typical floor does not equal the block load of that floor because the zone peak loads may all not appear at the same time.

Heat enters a space and transfer to the space air from either an external source or an internal source is mainly in the form of convective heat and radiative heat transfer.

Consider radiative heat transfer, such as solar radiation striking the outer surface of a concrete slab as shown in figure below.

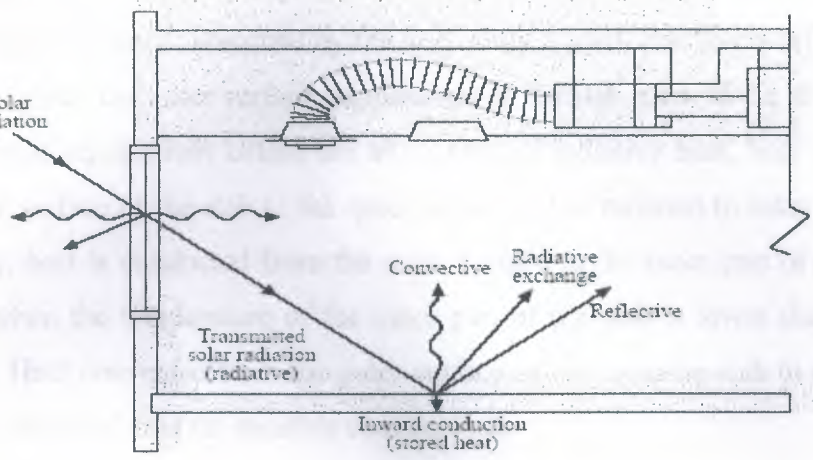


Figure 3.1(a) Convective and radiative heat transfer

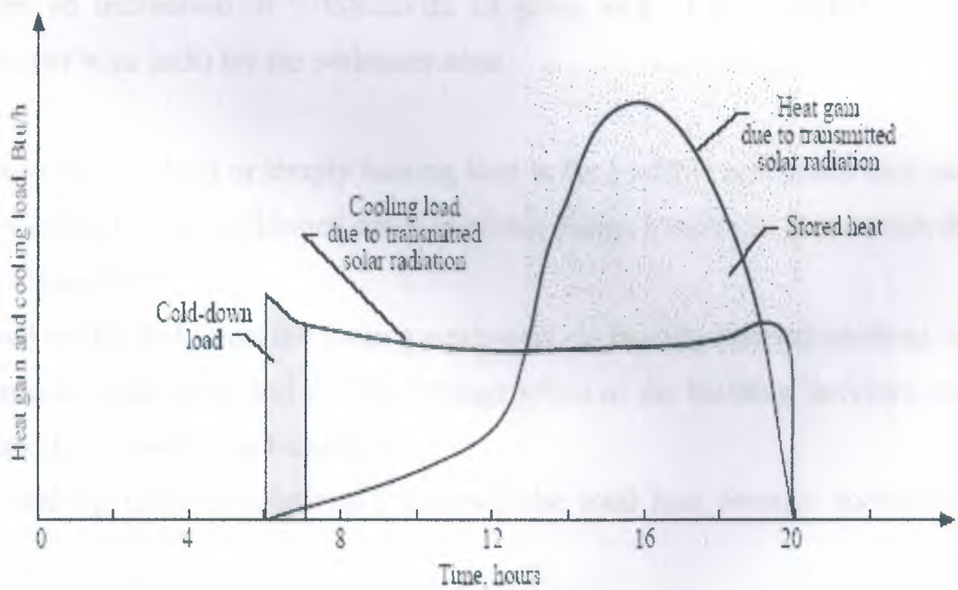


Figure 3.1(b) Heat gain and cooling load curves.

Solar heat gain from west window and its corresponding space cooling load for a night shutdown air system: (a) convective and radiative heat transfer and (b) heat gain and cooling load curves.

Most of the radiative heat is absorbed by the slab. Only a small fraction is reflected. After the heat is absorbed, the outer surface temperature of the slab rises. If the slab and space air are in thermal equilibrium before the absorption of radiative heat, heat is convected from the outer surface of the slab to the space air as well as radiated to other surfaces. At the same time, heat is conducted from the outer surface to the inner part of the slab and stored there when the temperature of the inner part of the slab is lower than that of its outer surface. Heat convected from the outer surface of the concrete slab to the space air within a time interval forms the sensible cooling load.

Infiltration is the uncontrolled inward flow of unconditioned outdoor air through cracks and openings on the building envelope because of the pressure difference across the envelope. The pressure difference is probably caused by wind pressure, stack effect due to outdoor–indoor temperature difference, and the operation of an air system(s). For hotels, motels, and high-rise residential buildings, ASHRAE/IES Standard 90.1-1989 specifies an infiltration of 0.038cfm/ft2 of gross area of the external wall, 0.15 air changes per hour (ach) for the perimeter zone.

The space heating load or simply heating load is the possible maximum heat energy that must be added to the conditioned space at winter design conditions to maintain the indoor design temperature.

It is used to size and select the heating equipment. In heating load calculations, solar heat gain, internal heat gains, and the heat storage effect of the building envelope are usually neglected for reliability and simplicity.

While making these calculations I followed the total heat transfer coefficients tables below:

Horizontal Brick	W-1	1.3
Vertical double brick with air gap	W-2	1.1
Vertical double brick with isolation	W-3	0.9
Ytong	W-4	0.7

Table 3.2(a) Walls covered with plaster on both sides

Wooden single glazed	Wood-SG	4.5
Wooden double glazed	Wood-DG	2.8
Metal single glazed	Metal-SG	5.0
Metal double glazed	Metal-DG	3.4
PVC single glazed	PVC-SG	4.3
PVC double glazed	PVC-DG	2.2
Wooden door		3.0

Table 3.2 (b) Windows – Doors

Floor	1.8
Roof	2.0

Table3.2(c) Floors & Roofs

Total Heat Transfer Coefficients Ikcal/h-m2

CHAPTER FOUR
RESULTS

ELECTRICAL INSTALLATION

4.1 Control Circuits

4.1.1 Wye-Delta Starters

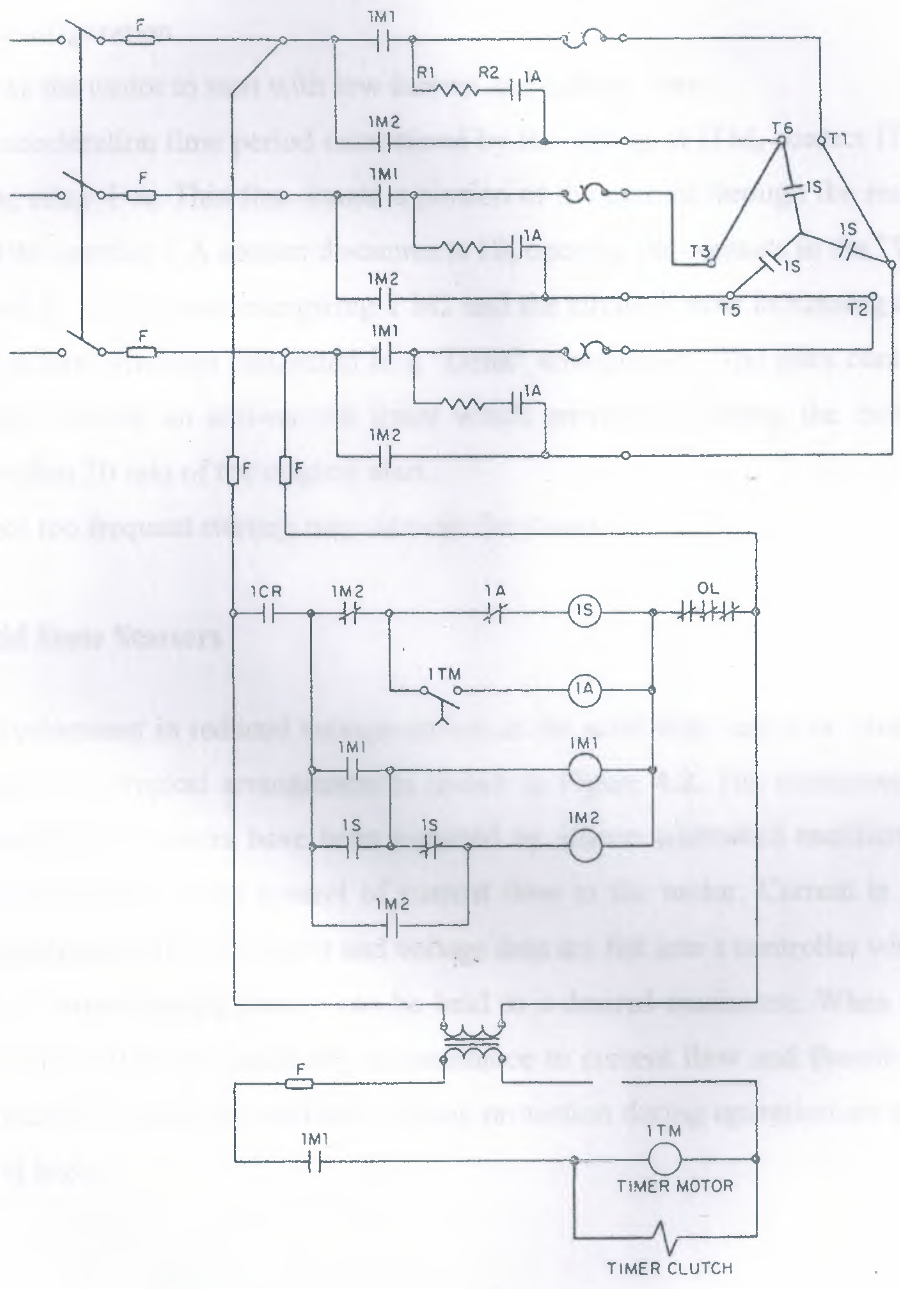


Figure 4.1 Wye-Delta Starter

Wye-Delta starters require specially wound motors, but have excellent starting characteristics, especially with very large motors. They are available with both open- and closed-transition arrangements.

A pilot control circuit (not shown) activates control relay 1 CR. Contact 1 CR closes and energizes relay 1S. This in turn energizes 1 M 1 and the motor windings are energized in a "Wye" configuration.
This allows the motor to start with low current and voltage draw.
After an acceleration time period determined by the setting of lTM, contact lTM closes, energizing relay 1 A. This first shunts a portion of the current through the resistors and then the late-opening 1 A contact disconnects 1S, opening the contacts in the "Wye." The NC contact in 1S re-closes energizing 1 M2 and the circuit is now in running configuration with motor windings connected in a "Delta" arrangement. The pilot control circuit will usually include an anti-recycle timer which prevents restarting the motor if it is stopped within 20 min of the original start.

Note that too frequent starting may damage the starter.

4.1.2 Solid State Starters

A new development in reduced voltage starters is the solid state starter or what so called "soft starters". A typical arrangement is shown in Figure 4.2. The contactors found in electro-mechanical starters have been replaced by silicon controlled rectifiers (SCR's), which provide proportional control of current flow to the motor. Current is sensed by current transformers (CT). Current and voltage data are fed into a controller which drives the SCR's. Current during startup can be held to a desired maximum. When the SCR's are fully "on" they offer essentially no resistance to current flow and therefore act like closed contacts. Overcurrent and low-voltage protection during operation are inherent in the control logic.

NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

INSTALLATION OF CENTRAL AIR CONDITIONING SYSTEM

Graduation Project
EE- 400

Student: Mohamed Elamin (20001017)

Supervisor: Asst. Prof. Dr. Doğan Haktanır

Lefkoşa - 2006

CHAPTER ONE

INTRODUCTION

Air-conditioning design is a process of selecting the optimum system, subsystem, equipment, and components from various alternatives and preparing the drawings and specifications. This process is summarized in four phases: gather information, develop alternatives, evaluate alternatives, and sell the best solution. Design determines the basic operating characteristics of a system. After an air-conditioning system is designed and constructed, it is difficult and expensive to change its basic characteristics.

The foundation of a successful project is teamwork and coordination between designer, contractor, and operator and between mechanical engineer, electrical engineer, facility operator, architect, and structural engineer.

Air-conditioning is a process that simultaneously conditions air; distributes it combined with the outdoor air to the conditioned space; and at the same time controls and maintains the required space's temperature, humidity, air movement, air cleanliness, sound level, and pressure differential within predetermined limits for the health and comfort of the occupants, for product processing, or both.

Therefore, the goal of an air-conditioning system is to provide a healthy and comfortable indoor environment with acceptable indoor air quality, while being energy efficient and cost effective.

Theoretically, an air-conditioning system consists of equipment that provides an atmosphere that controls temperature, humidity, and purity at all times, regardless of weather conditions. In popular usage, however, the term air conditioning often is applied improperly to air cooling. Many so-called air-conditioning units consist merely of blower-equipped refrigerating units that provide only a flow of cool, filtered air.

Acceptable indoor air quality is defined as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

An air-conditioning consists of components and equipments arranged in sequential order to heat or cool, humidify or dehumidify, clean and purify, attenuate objectionable equipment noise, transport the conditioned outdoor air and recirculate air to the conditioned space, and control and maintain an indoor or enclosed environment at optimum energy use.

The use of electricity for heating purposes has long been favoured because it offers certain advantages over other sources of heat. There is an absence of fumes; heat is available immediately at any desired temperature; there is an ease of control; cleanliness is an important factor; and there is a reduction in the amount of labour required for operation as compared with other fuel systems. In recent years there has been an increase in the applications of electricity to provide heat, not only for domestic purposes, but also for industrial processes.

The multi-split systems have come of age in the last 5-10 years and are particularly popular because they require less outdoor plant space than conventional systems, are less disruptive to fit in existing buildings (particularly when occupied), are able to cool and heat through common pipe work and sometimes have inherent heat recovery.

These systems all use refrigerant as the cooling and heating medium rather than chilled water and hot water as is used in conventional hydraulic systems circulated by pumps.

Condensing units are used externally when cooling only is required and heat pumps are used externally when both cooling and heating are required.

The traditional split system is also known colloquially and more descriptively as a one to one split system, meaning one external condensing unit or heat pump is connected by refrigerant pipe work to one indoor cooling / cooling and heating unit.

The multi-split system uses one external unit which is connected to several indoor units. The multi-split system takes a number of different forms and it is essential the designer understands the limitations of each type of system.

One off external condensing unit is connected to several indoor units as is typical for a multi-split system. One of the indoor units is provided with temperature controller and acts as master and the other units act as slaves. All indoor units will therefore function as the master setting. Master and slave units are suitable for single areas, single rooms or even multiple rooms with very similar heat gains and losses. They are not suitable for individual areas which have different heat gain and loss characteristics because the master control will sense air temperature for one area room only and the areas will overcool or overheat.

The area, Onar Village, is situated on a skirt of the Kyrenia mountain range, about five minutes from the city centre. Its unique, 180-degree panoramic view overlooks the northern Mediterranean Sea and the ancient town of Kyrenia. It covers a total area of 1617m^2 (29.32X5515).

Figure 1.1 Onar village

CHAPTER TWO
REVIEW OF LITERATURE

2.1 System equipments

2.1.1 Economizer Cycles

A number of options exist for heat recovery in conditioned spaces. The selection depends on site conditions and economics. The main categories are:

- Air-to-air heat recovery
- Direct evaporative cooling
- Combination (3-stage) cycles
- Outdoor air or ventilation cycle
- Indirect evaporative cooling
- Chiller "free" cooling

Air-to-air Heat Recovery - is often referred to as the exhaust air heat recovery cycle, since heat is recovered from the warm air exhausted from a building or process. Categories include:

- Process-to-process,
- Process-to-comfort,
- Comfort-to-comfort.

Within these categories there are different options. Making the selection is often dependent on the proximity of the exhaust to the supply air ducts. Consider these factors when making an evaluation:

- Energy costs
- The amount of useable waste
- The temperature of waste heat
- Other conservation options
- The effects on the HVAC system

- The effect on relative humidity
- The proximity of the supply and demand

Where exhaust and supply air ducts are not in close proximity, consider the glycol "run-around" loop system.

The rising costs of all forms of energy and the pressures to conserve water have focused attention on the issue of heat recovery: collecting heat that would otherwise be rejected in exhaust air or cooling towers and using it to augment the heating or cooling process. In an ideal heat recovery system, all components work year-round to recover the internal heat before adding external heat.

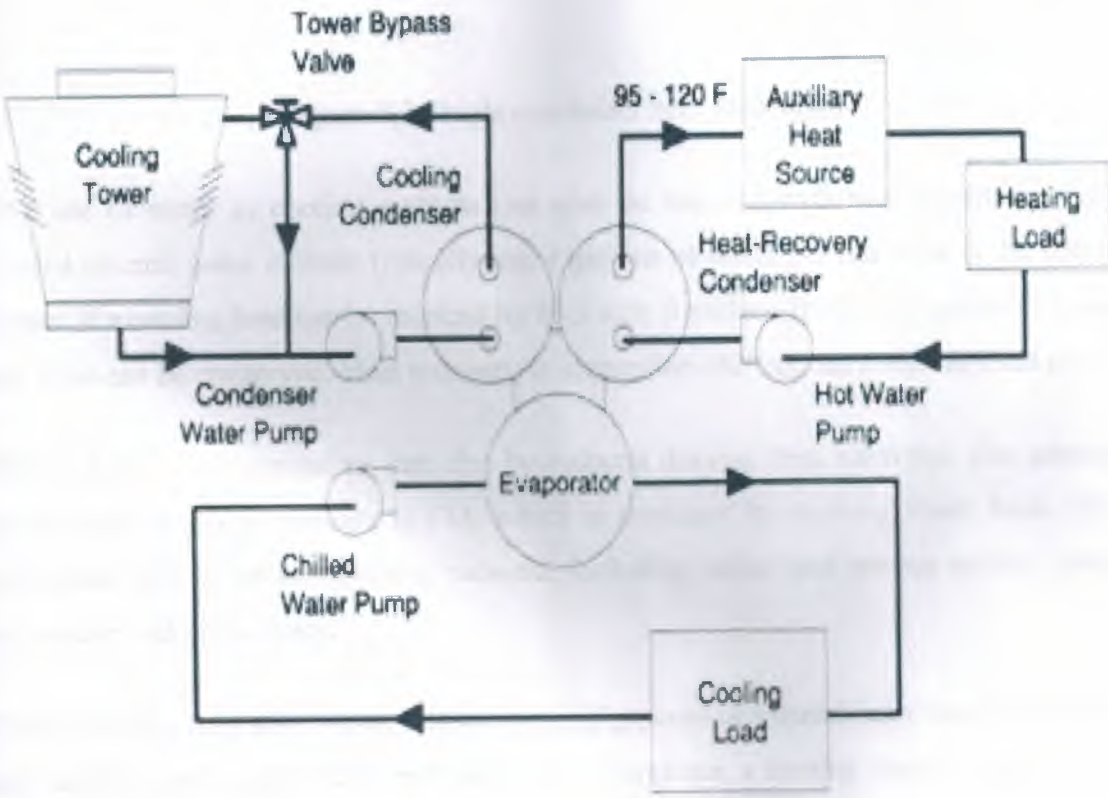


Figure 2.1 General system

The term for this concept is balanced heat recovery. However, few systems are this ideal. In any event, a significant amount of waste heat can often be economically recovered.

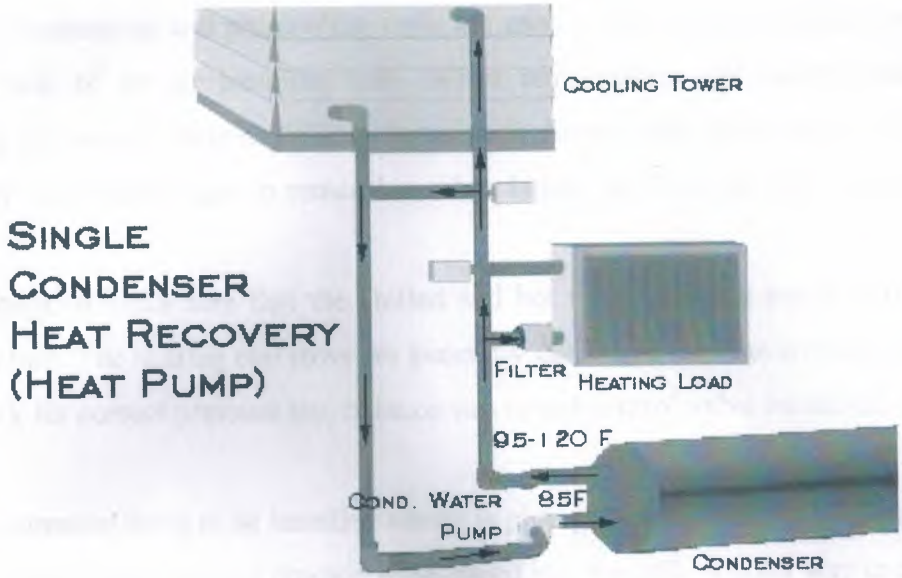


Figure 2.2 Single condenser heat recoveries

The use of water in cooling systems can also be reduced with heat recovery. Water-cooled electric water chillers typically use 4 gallons of water per ton-hour in the cooling tower. If a cooling load can be reduced by 83.3 tons (l million Btuh), 333 gallons of water per hour can be conserved. Heat recovery in absorption chillers can conserve even more.

Site and source air emissions can also be reduced through heat recovery. The principal contributor to global warning is CO_2 which is produced by burning fossil fuels. Other emissions will be proportionately reduced, including sulfur and nitrous oxides, carbon monoxide and particulates.

Other benefits may also occur. For example, if process or internal heat can be recovered and used, it could reduce the need for, or even eliminate, a cooling tower or other device used to reject previously unwanted or unused waste heat.

2.1.2 Coils

Coils can be used for many different applications such as: cooling, heating, pre-heating, pre-cooling, and re-heating. The three types of fluids used are: water, refrigerant, and steam. Preheating and pre-cooling coils are used to heat or cool outside air coming into the back of an air handling unit. When temperatures get below freezing the preheating coil would come on to keep water coils downstream from freezing. There are a few very important things to remember when balancing flow through a chilled water coil:

Always check to make sure that the chilled and hot water is being piped to the correct coil in the unit. The heating coil rows are generally much less than the cooling coil.

Also check for correct pressure tap, balance valve, and control valve locations.

The most common thing to be installed wrong is piping the coil backwards. This is where the supply and return lines get crossed when piped into the coil. A great way to check this is to remember the saying "Warmest Water hits the Warmest Air". This means that the warm air or return air should be hitting the warm water or return water first.

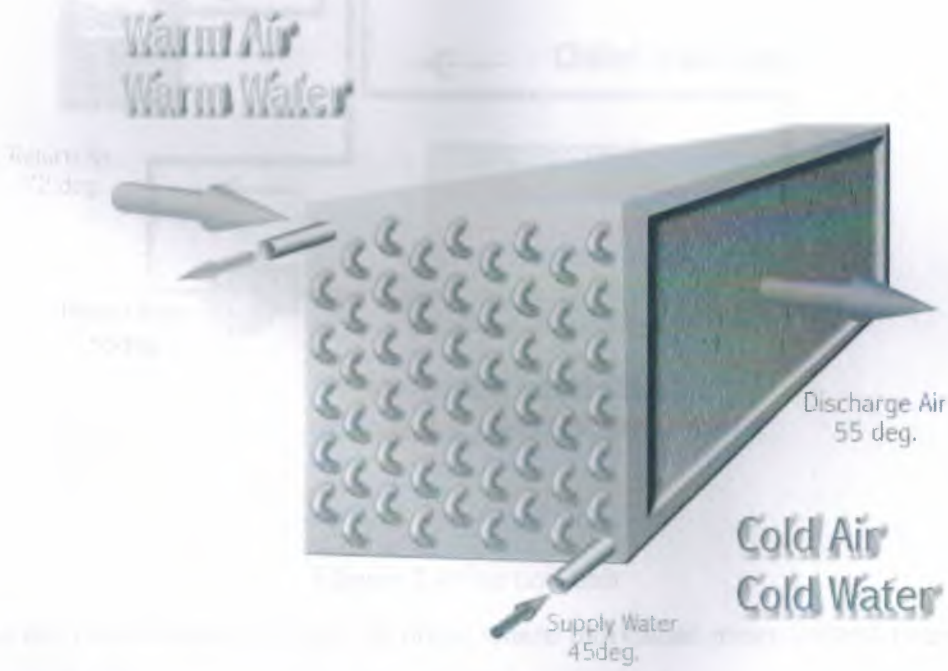


Figure 2.3 Coil

2.1.2.1 Fan Coil/Unit Ventilator Systems

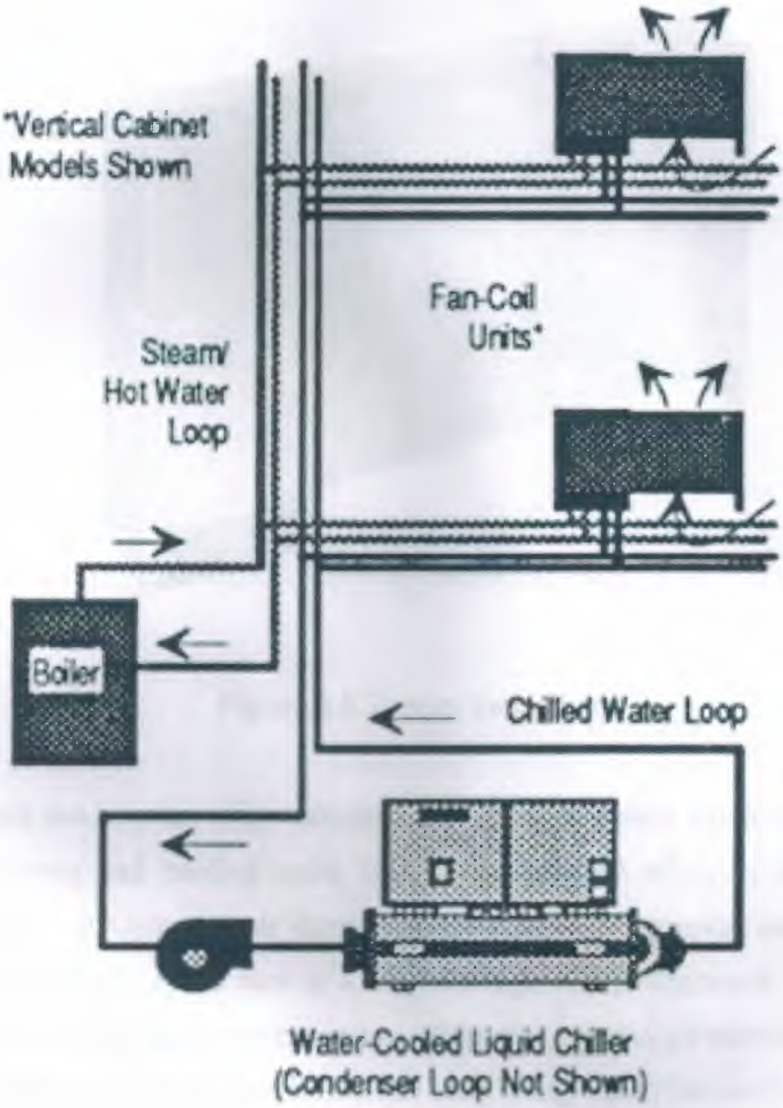


Figure 2.4 Fan coil unit

Fan coils are most commonly used in areas where individual room control is essential, such as hotels, private and public office buildings, hospitals and schools. Fan coils and unit ventilators are excellent examples of single-zone systems. These systems are available in horizontal ceiling mounted, concealed, or recessed vertical floor mounted arrangements. These systems are typically sized based on peak airflow, but the central refrigeration and heating sources are based on typical loads.

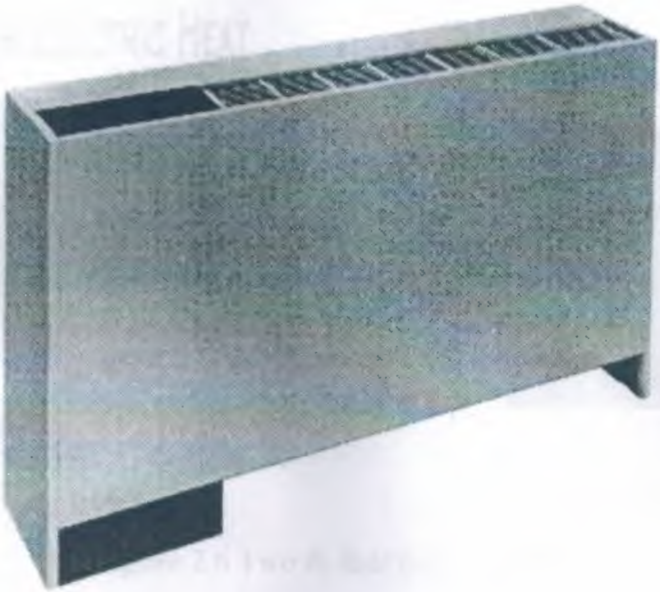


Figure 2.5 Type of fan coil unit

These systems use in-room units contained in a common casing where components such as a fan, heating and cooling coils, filters, controls and often, in the case of unit ventilators, the outside/return air damper are packaged. A common configuration uses low pressure, multiple speed fans in a blow-through coil arrangement. A chilled water cooling coil is typical, but direct expansion refrigerant systems are also used. The heating coil can be hot water, steam or electric. For coils using water, two or four-pipe systems are very common. Where wall penetrations are not acceptable, ventilation can be supplied by a separate system.

Fan Coil/Unit Ventilator Systems are:

- Two-Pipe system.
- Four-Pipe system.

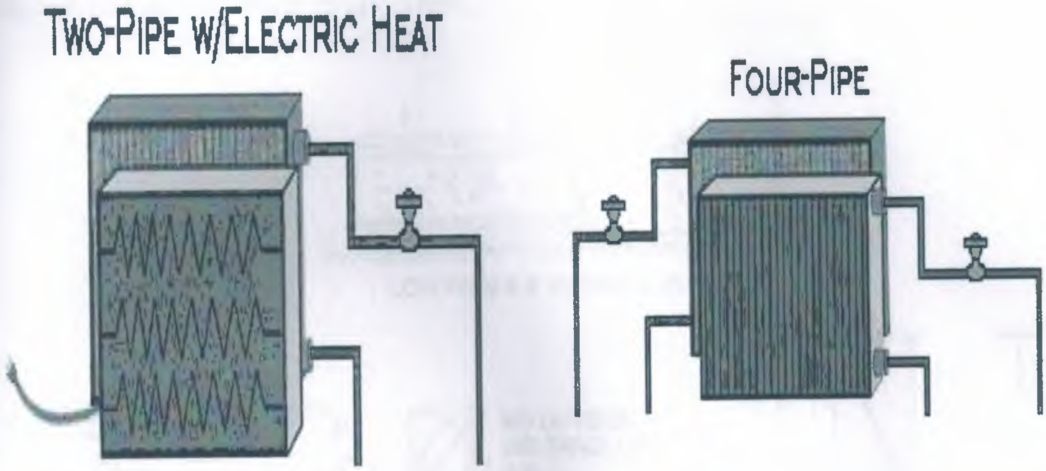


Figure 2.6 Two & four pipe systems

For two-pipe applications, the system designer must consider the change-over from cooling to heating duty. Multiple chillers and/or boilers may be required for multiple zones. Unit mounted controls utilize a pipe-mounted sensor to "tell" the unit whether it is heating or cooling, thereby opening or closing the closing valves accordingly.

Four-pipe systems utilize two independent coils, one for heating and one for cooling, Cooling and heating valves for controlling coil capacities are often factory installed with their controls hidden inside the cabinet , wall-mounted, or remotely mounted to prevent students or other occupants from tampering with them.

Two-pipe systems use a single coil for cooling or heating. A two-pipe system with intermediate season electric heating is a popular first-cost choice versus a four-pipe system. In the summer and intermediate seasons, the unit calls for cooling when the room temperature rises above the set point. If the room temperature drops too far below the set point, the cooling valve closes and the electric heat is energized.

The advantage of a two-pipe system with an electric heated fan coil tends to be recognized during the transition months (fall or spring) when cooling or heating can be required in the same day. The change-over is automatic with a system utilizing a thermostat that senses water temperature.

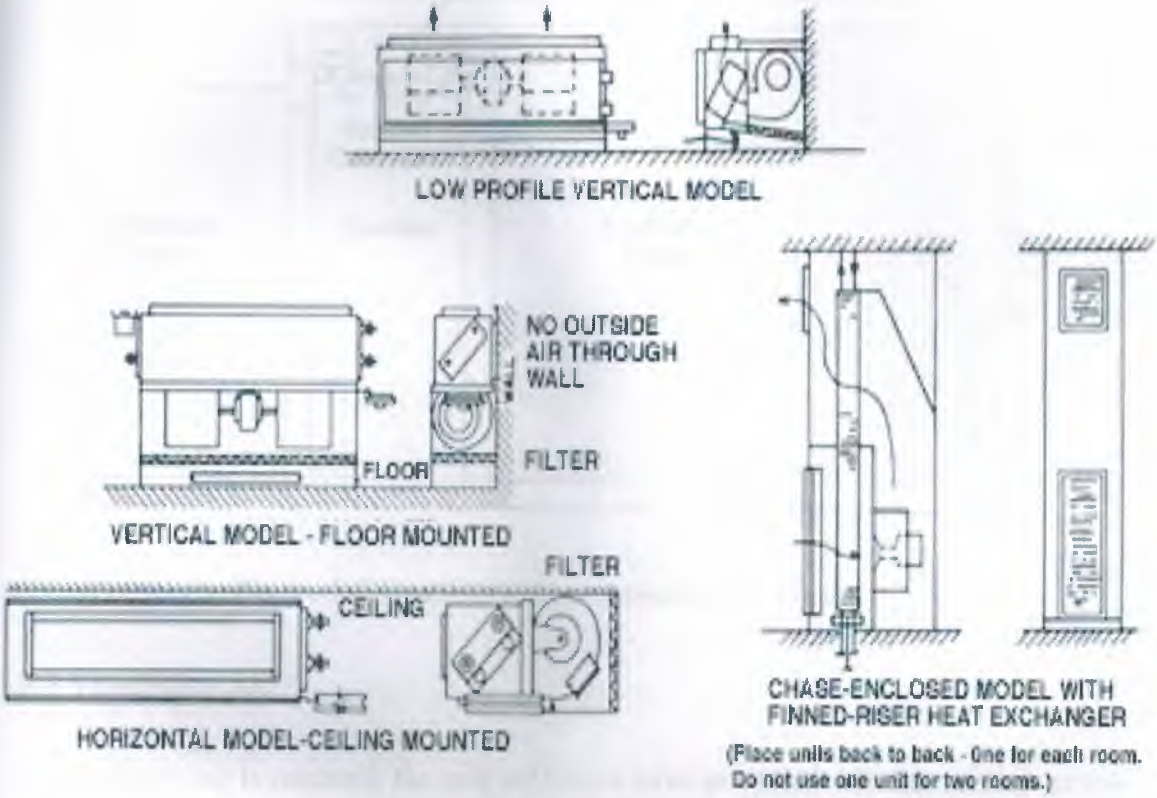


Figure 2.7 Typical fan-coil unit arrangements

2.1.2.2 Fan Coil/Unit Ventilator Systems - Application Considerations

Fan coils or unit ventilators are typically installed around the perimeter of a building, on walls, under windows or suspended in the ceilings. A mechanical equipment room on each floor is unnecessary. Perimeter setting provides easy access to outside air. However, in some cases, architecturally attractive grilles are used or outside air can be introduced through a central shaft. Perimeter setting also makes it easier to run coil piping and condensate drain connections to each unit.

Both unit ventilator and fan coil systems have filters and fan drive components that require periodic maintenance. Service and maintenance could interrupt occupants. Therefore, ease of access is important when specifying either of these units.

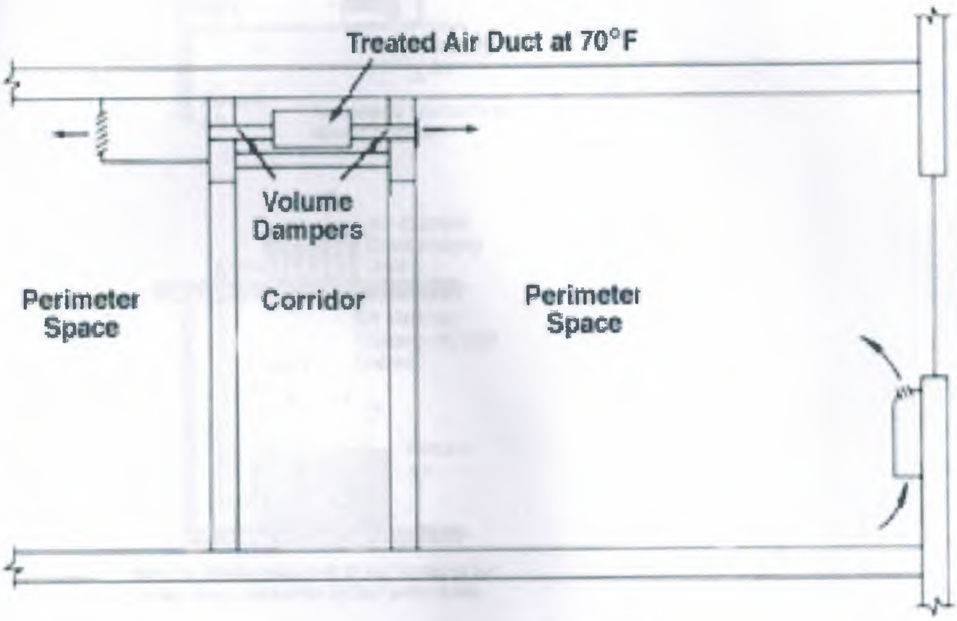


Figure 2.8 Ventilation form separate duct system

2.1.2.3 Ventilation Air

If outside air is required, the unit will often have an outside air damper that mixes outside air with return air inside the unit cabinet. This also enables an air economizer cycle where air is used for cooling purposes. Air intake grilles on a building's exterior provide a path for outside air to enter the unit.

2.1.2.4 Differences between Unit Ventilator and Fan Coil Systems

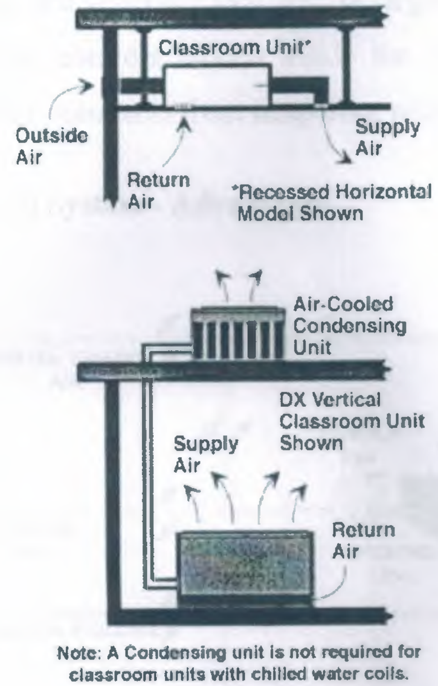


Figure2.9 Air conditioner

One main difference is in the unit cabinetry. Unit ventilators typically have heavier sheet metal cabinets which hold up better in the school environment. Classroom unit ventilators also have architectural advantages. School room units can have shelving or cabinetry built alongside the unit to help hide the comfort source.

Another difference is that unit ventilators are usually designed to deliver large amounts of outside air through exterior wall openings. Indoor air quality has become a major issue, especially in schools. ASHRAE Standards recommend ever larger percentages of outside air per student (i.e. 15 cfm per student). This results in larger ventilation loads. A classroom unit ventilator is specifically designed to handle these loads. In addition, utilizing chilled water and hot water coils allows for more stable control of coil discharge air temperature than with a direct expansion coil.

Heat gains can be as large as 7°F when a classroom suddenly fills with students. By taking in the outside air, unit ventilators can provide "free cooling" during cooler weather. A discharge air thermostat maintains a minimum leaving air temperature from the unit to prevent "dumping" of cold air onto students seated near the unit.

Unit ventilators are generally available in larger sizes than fan coils, and both unit types often have their controls hidden inside the cabinet or remotely mounted to prevent students or other occupants from tampering with them.

2.1.2.5 Fan Coil System - Advantages

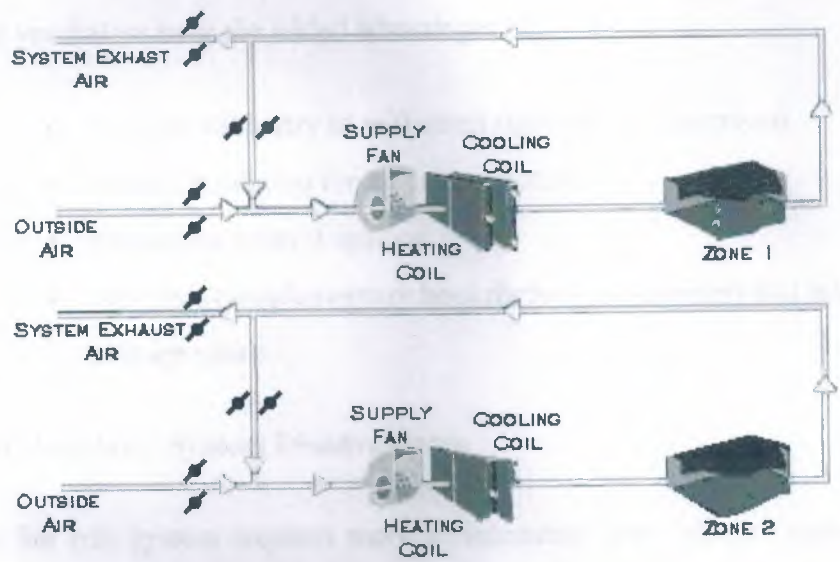


Figure 2.10 Fan coil unit ventilator

1. Central equipment may be sized smaller by taking advantage of building heating and cooling diversity.
2. The system requires only piping installation which takes up less space than all-air duct systems.
3. It is usually easier to install wire and water pipes than ducts making this a good choice for retrofit applications.
4. Unoccupied areas of the building may be isolated and shut down, saving money.
5. Zones can be individually controlled.
6. The system can accommodate up to 100% outside air capability.

2.1.2.6 Fan Coil System - Disadvantages

1. The Fan Coil System requires more maintenance than "all air" systems, and the maintenance work (such as servicing filters) is performed in occupied areas.
2. Condensate must be disposed of at each unit.
3. Interior zones may require separate ducts to deliver outside (ventilation) air.

2.1.2.7 Unit Ventilator System Advantages

Unit ventilators have the added advantages of:

- Heavier cabinetry to withstand rigors of the classroom
- Added insulation for quieter operation
- Numerous control options
- Optional complementary bookshelves and cabinets that add valuable storage space.

2.1.2.8 Unit Ventilator System Disadvantages

1. The fan coil system requires more maintenance than "all air" systems, and the maintenance work (such as servicing filters) is performed in occupied areas.
2. Condensate must be disposed of at each unit.
3. Interior zones may require separate ducts to deliver outside air.

Large exterior wall openings are required at each unit to accommodate 100% outside air capability.

2.1.3 The Condenser

The refrigerant is recovered by condensing it in a heat exchanger using air or water to reject the heat. Air cooled condensers are most common in smaller sizes, up to about 200 ton capacity. Technically, there is no upper limit on the size of an air cooled condenser, but operating cost issues usually dictate water cooled units for applications over about 100 tons.

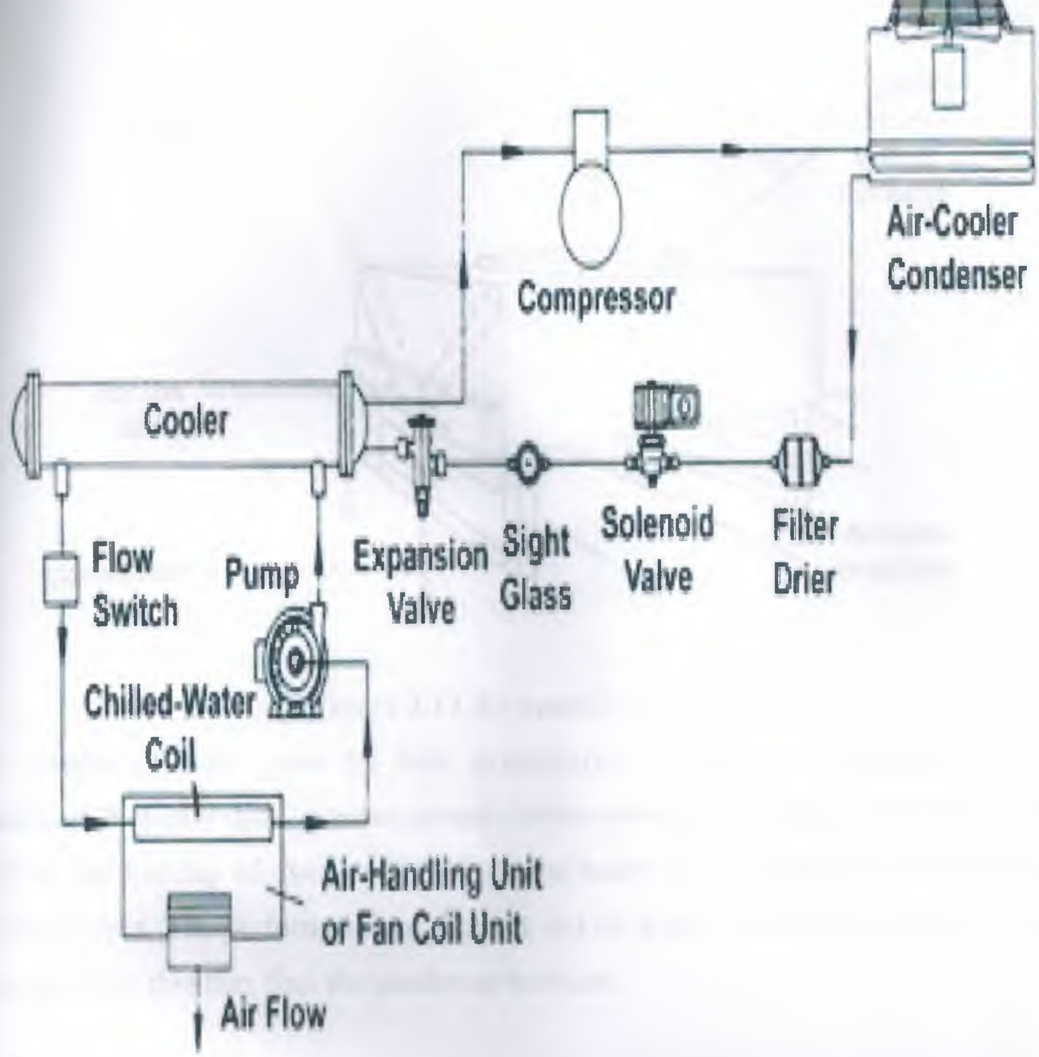


Figure 2.11 Condenser cycle

There are two water cooled designs:

- Cooling towers.
- Evaporative condensers.

Both work on the principal of cooling by evaporating water into a moving air stream. The effectiveness of this evaporative cooling process depends upon the wet bulb temperature of the air entering the unit, the volume of air flow and the efficiency of the air/water interface.

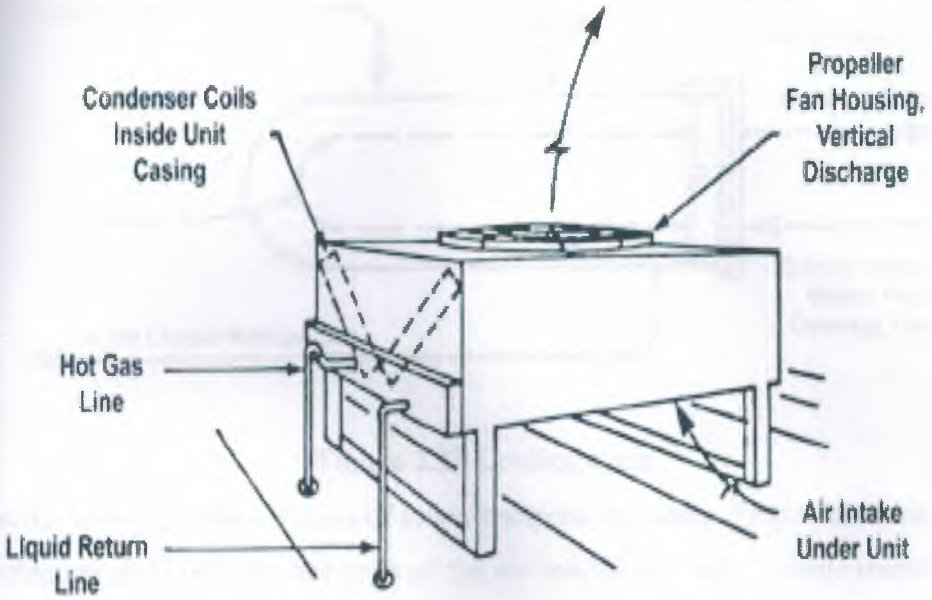


Figure 2.12 Air cooled condenser

The volume of water used by both evaporative condensers and cooling towers is significant. Not only does water evaporate just to reject the heat, but water must be added to avoid the buildup of dissolved solids in the basins of the evaporative condensers or cooling towers. The performance of the unit can be greatly reduced if these solids build up to the point that they foul the condenser surfaces.

2.1.3.1 Cooling Towers

Cooling towers are essentially large evaporative coolers where the cooled water is circulated to a remote shell and tube refrigerant condenser. Notice the cooling water is circulating through the tubes while refrigerant vapor condenses and gathers in the lower region of the heat exchanger. Notice also that this area "sub cools" the refrigerant below the temperature of condensation by bringing the coldest cooling tower water into this area of the condenser. The warmed cooling water is sprayed over a fill material in the tower. Some of it evaporates in the moving air stream. The evaporative process cools the remaining water.

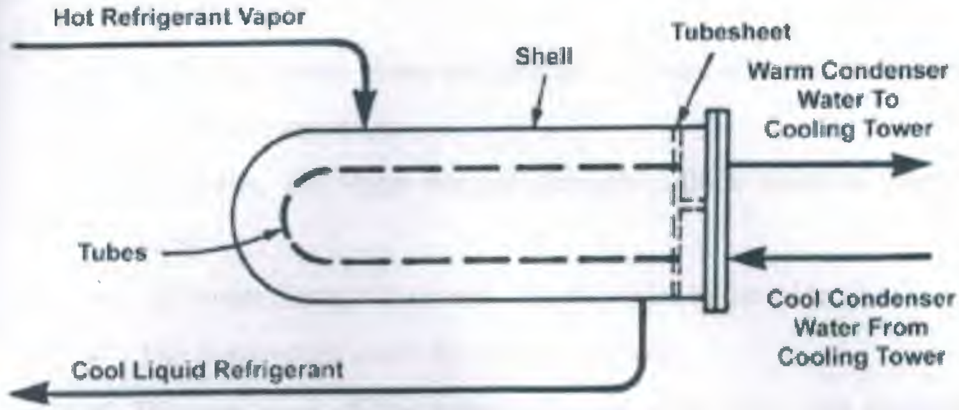


Figure 2.13 Cooling cycle

The cooling tower creates a stream of lower-temperature water. This water runs through a heat exchanger and cools the hot coils of the air conditioner unit. It costs more to buy the system initially, but the energy savings can be significant over time (especially in areas with low humidity), so the system pays for itself fairly quickly.

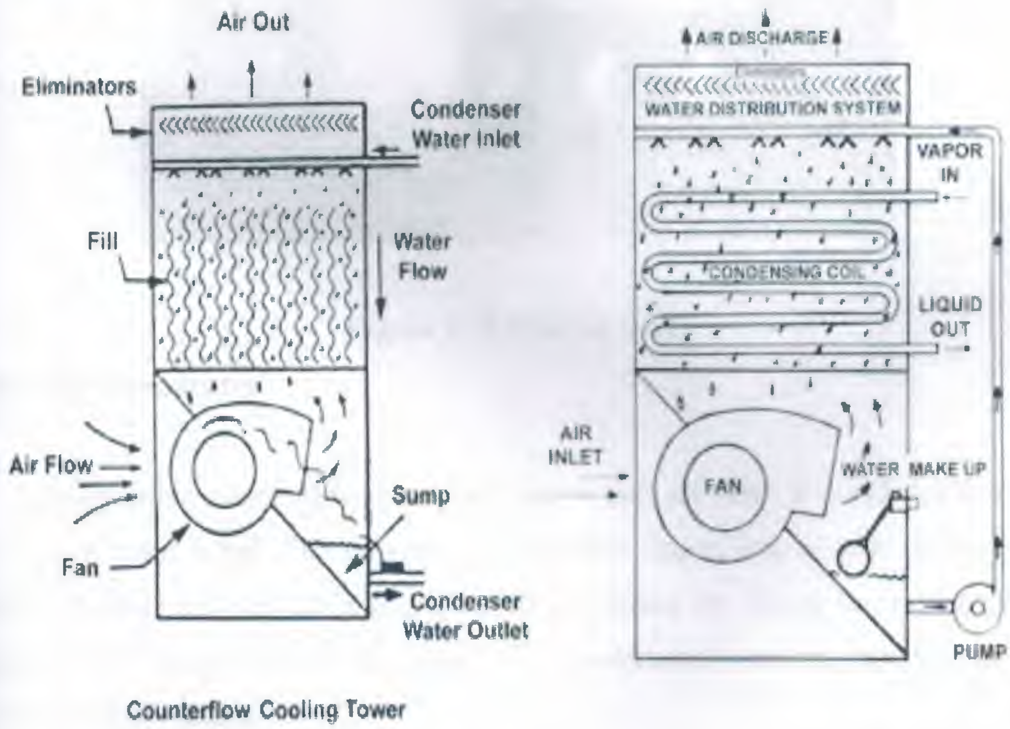


Figure 2.14 Counter-flow cooling tower

Cooling towers come in all shapes and sizes. They all work on the same principle:

- A cooling tower blows air through a stream of water so that some of the water evaporates.
- Generally, the water trickles through a thick sheet of open plastic mesh.
- Air blows through the mesh at right angles to the water flow.
- The evaporation cools the stream of water.
- Because some of the water is lost to evaporation, the cooling tower constantly adds water to the system to make up the difference.

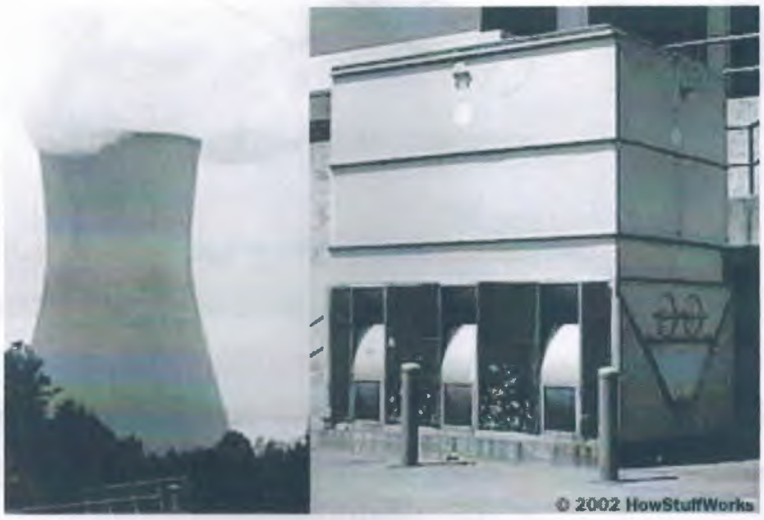


Figure 2.15 Cooling tower

2.1.3.2 The Evaporator

Evaporative condensers use water sprays and air flow to condense refrigerant vapors inside the tubes. The condensed refrigerant drains into a tank called a liquid receiver. Refrigerant sub cooling can be accomplished by piping the liquid from the receiver back through the water sump where additional cooling reduces the liquid temperature even further.

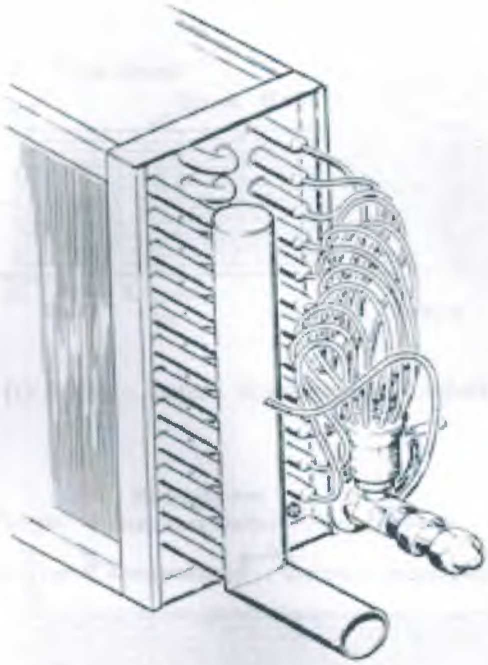


Figure 2.16 Evaporator

On the design day the evaporator typically cools either:

1. Air returning from the building space (or outside air) to 55 - 60°F
2. Water from about 54°F as it returns from building air handlers to 44°F.

In both cases the evaporator boils the selected refrigerant to provide this cooling. The pressure at which the refrigerant boils is exactly that which satisfies the energy balance of heat-in equals heat-out.

The refrigerant is circulated through numerous parallel paths. The pressure will drop as the refrigerant flows and evaporates along these paths. This in turn drops the temperature of the refrigerant as it evaporates. Consequently, properly designed direct expansion coils operate with the coldest refrigerant temperatures closest to the coil exit. However, the refrigerant temperature coming out of this coil is usually a little warmer than this to provide some level of superheat to be sure liquid refrigerant isn't leaving the coil and entering compressor (where it could cause mechanical failure in some designs).

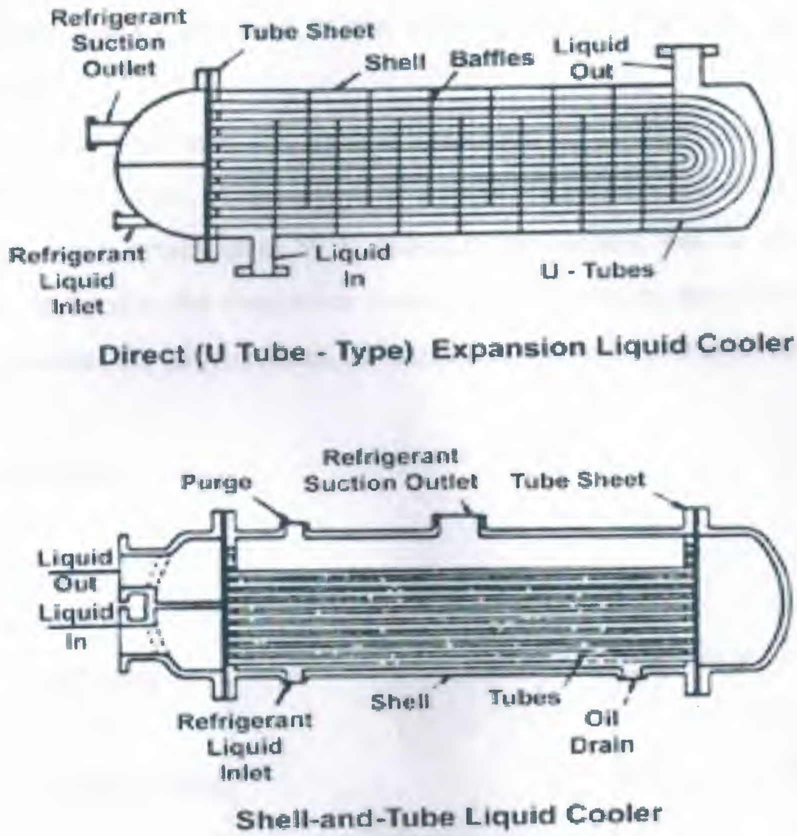


Figure 2.17 Liquid coolers

Shell and tube heat exchangers commonly have water circulated through the tubes and refrigerant boiling around the tubes. There are also designs where refrigerant flows within the tubes and water flows over the tubes. Baffles are normally used in this case to direct water flow in a serpentine fashion to optimize heat transfer. Almost all large chillers use shell and tube evaporators with water flowing through the tubes.

2.1.3.3 Vapor Compression Systems - Evaporator Control

In comfort cooling applications, actual cooling loads are seldom at full load conditions. Capacity control is achieved in finned coil evaporators that directly chill air by splitting the coil into independent sections. The principal reason is to permit coil sections to be activated and deactivated to better match coil cooling capacity with compressor loading. The combination of smaller coil sections controlled by correspondingly sized expansion valves improves valve performance and part load humidity control.

Capacity control in shell and tube evaporators is usually handled using the return water temperature. For example, if the full-load temperature range for chilled water is from 44°F to 54°F, water returning at 50°F indicates the cooling load is about 60%. Liquid refrigerant is metered to the evaporator to match the load using an orifice plate system or an expansion valve. On large chillers, the expansion valve is pilot operated.

2.1.4 Storage Tanks

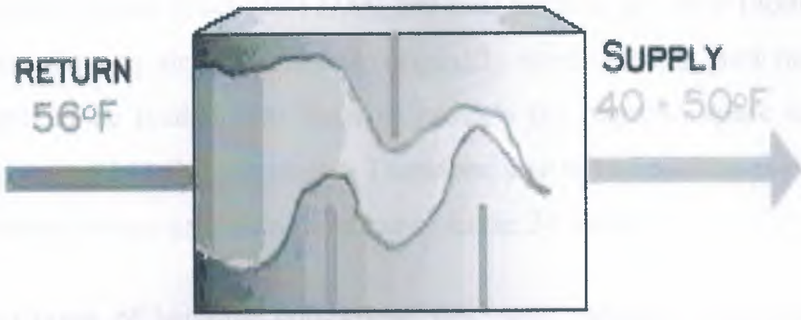


Figure 2.18 Storage tank

The simplest form of chilled water storage places one or more tanks in series in the de-coupler line. This is shown in this single baffled tank. Now, when the chillers produce more chilled water than the system requires, the excess is diverted to the series tank where it displaces the warmer water there. Likewise, when chilled water demand exceeds the quantity produced, chilled water is drawn from the storage tank by displacing it with warm return water.

A number of chilled water storage systems with designs similar to this have been installed and have proven to be fairly effective in reducing on-peak electrical demand. However, series tank design can cause the water to stratify or become stagnant. Stagnation is the tendency of water to shortcut its way through the tank, and renders large volumes of the tank ineffective for Btu storage. Furthermore, inter-compartmental mixing raises the tank's leaving water temperature as it empties. This reduces tank effectiveness during its final hours of discharge.

2.2 Cooling Capacity

Cooling systems are defined by:

1. The temperatures they can hold either in the space and/or the process or equipment.
2. The amount of heat they can remove at full capacity.

This heat removal is normally expressed in tons of cooling (or refrigeration) capacity. One ton of cooling equals precisely 12,000 Btu heat removal per hour (abbreviated Btuh) and comes from the way air handlers were originally rated -- that is, how many pounds of ice would have to be loaded into them to provide the required space cooling. When melting, ice gives up 144 Btu per pound. Therefore, one ton of cooling provides the same amount of cooling energy as melting one ton of ice in 24 hours.

For any given piece of installed equipment, this rated capacity is dependent upon the method used by the system to reject heat. For example, a cooling system rejecting heat to a dry fan-coil condenser will normally produce fewer tons of cooling on the design day than that same chiller mechanical system rejecting heat to a cooling tower. Put another way, any cooling system uses more power (or thermal input in the case of absorption chillers) to reject heat to a dry (air cooled) condensing system than to a wet (water cooled) condensing system.

This energy performance is defined by several measures: Coefficient of Performance (COP), kW/ton, Energy Efficiency Ratio (EER), and similar terms for thermally activated systems. The energy efficiency rating (EER) of an air conditioner is its BTU rating over its wattage. For example, if a 10,000-BTU air conditioner consumes 1,200 watts, its EER is 8.3 (10,000 BTU/1,200 watts). Obviously, you would like the EER to be as high as possible, but normally a higher EER is accompanied by a higher price

Most air conditioners have their capacity rated in British thermal units (BTU). Generally speaking, a BTU is the amount of heat required to raise the temperature of one pound (0.45 kg) of water 1 degree Fahrenheit (0.56 degrees Celsius). Specifically, 1 BTU equals 1,055 joules. In heating and cooling terms, 1 "ton" equals 12,000 BTU.

A typical window air conditioner might be rated at 10,000 BTU. For comparison, a typical 2,000-square-foot (185.8 m^2) house might have a 5-ton (60,000-BTU) air conditioning system, implying that you might need perhaps 30 BTU per square foot.

2.3 Chilled Water Temperature & Flow

Most large buildings use air handlers with chilled water coils. Historically, chilled water has been, supplied to these air handlers at ~ 44°F on the warmest days of the summer and would return to the chiller at about ~ 54 (i.e., 10°F warmer). Every ton of cooling delivered this way requires 2.4 gpm of water flow. Design professionals today have a multitude of alternatives available to them, including:

1. Increasing the difference between supply and return chilled water temperatures (called the chilled water range) to reduce chilled water pipe sizes and pumping power.
2. Increasing the coil surface area to permit higher chilled water supply temperatures,
3. And using lower temperature chilled water, perhaps in the 36 - 38°F range, to produce much colder supply air, thereby reducing air handler air flows, fan power, and duct sizing (which can even reduce building height).

These factors can impact energy use in complex ways. For example, distributing low temperature chilled water is often combined with increasing the chilled water range (e.g., supplying 38°F water and returning 58°F water). The chilled water flow is now only 1.2 gpm per ton, providing significant savings in chilled water distribution piping and pumps. However, producing 38°F water potentially requires more power and more expensive chiller designs. Certain building designs (such as churches, theaters, and operating room suites) can be "naturals" for ice storage. Similarly, chilled water at 40 - 42°F can sometimes achieve similar benefits.

All of these tradeoffs are complex and obviously fall within the domain of the design professional. Each design requires careful analysis, consideration of current and future building use, operating personnel qualifications, and the issues of initial investment and operating cost. This information is simply an explanation of some of the options available. Please refer to the specific cooling situation analyses elsewhere in this information system for further information.

2.3.1 Condenser Water Temperature & Flow

Chillers larger than about 100 tons usually have water circulating through the condenser. This water removes the heat from the chiller (the contribution due to the cooling as well as removing the heat from the motor, engine or absorber). Therefore a high efficiency electric chiller rated at 0.6 kW per ton rejects approximately 14,000 Btuh/ton of cooling. A high efficiency absorption chiller with a COP of 1.0 rejects about 24,000 Btuh/ton of cooling.

The circulating cooling tower water flow is determined primarily by the range in temperature. For example, with a high efficiency electric chiller, a 10°F range (e.g., supplying 85°F water to the chiller condenser and heating that water to 95°F), requires a condenser water flow of about 2.8 gpm per ton. With the same 10°F range, it would have to be about 4.8 gpm per ton for the high efficiency absorption chiller. This flow can be reduced by widening the range, but that would decrease the efficiency of the chiller itself.

The temperature of the water sent to the chiller condenser from the cooling tower is determined, largely by the ambient wet bulb temperature and the efficiency of the cooling tower (the amount of air drawn through the tower and the efficiency of air-water contact). Dry bulb temperature has only a minimal impact on cooling tower performance. The cooling tower is normally specified to meet the design wet bulb temperature in any geographic area -- commonly 75° to 78°F. The cooling tower manufacturer then designs the tower to produce 85°F water under this condition for the design heat rejection level and water flow. The temperature difference between the water sent to the condenser (i.e. coming off the cooling tower) and this wet bulb figure (say 78°F) is defined as the approach temperature 7°F (= 85 - 78).

This design day wet bulb condition occurs relatively few hours a year in most parts of the United States. During dryer times, the cooling tower can produce colder water than 85°F. And, most chillers will operate with reduced power input if this water temperature is reduced (down to a given limit as specified by the equipment manufacturer). This concept is called "floating the condenser" and holds the potential of conserving energy and reducing operating costs.

Selecting the condenser water parameters and cooling tower design is very complicated. Design of these systems requires experience, careful analysis, and consideration of initial investment and operating costs. The material presented here is simply an explanation of several design parameter opportunities. Please refer to the specific cooling design modules elsewhere in this information system for additional details.

2.4 Compressor Capacity and Performance

All compressors are rated in terms of how much flow they produce at a given ratio of outlet to inlet pressure (compression ratio). This flow is obviously a function of compressor size and operating speed (rpm), Compression ratio is defined by the discharge pressure divided by the suction pressure.

The limits of clearance volumes and valve pressure differentials force some of the compressor's flow volume capability to be lost as useful compression. This is referred to as volumetric efficiency. For example, at a compression ratio of 3 to 1, 82% of the volume of the compressor is useful. Therefore, if the refrigeration effect required 10 cfm of vapor flow from the evaporator, the compressor would have to produce 10/.82 or 12.2 cfm of flow.

2.5 System Economics

Most people make a purchase to solve a real or perceived problem. They use economic evaluations to justify their decision. With chillers, problems can range from inadequate capacity, chiller failure or high energy bills to the fear of CFC issues. In this section we will address the economics of chiller alternatives. A number of factors influence the costs of owning and operating large water chillers. These include:

1. Installed first cost, including any building modifications to accommodate one particular alternative over others.
2. Operating costs, including all the fuel, electric, and water costs (including the acquisition, treatment, and disposal of sewered water) to accommodate one alternative over others.
3. Maintenance costs, including preventive maintenance and the monitoring of refrigerants to minimize losses. Materials and supplies are also included here.
4. Insurance and Property Taxes.
5. Replacement Provisions, which takes into account the useful lives of the alternatives.
6. Financing, depreciation, and income taxes should also be considered. The money invested has a time value (interest) and there are usually tax consequences that affect decisions. It's usually a good idea to consult a tax accountant.
7. Method of evaluation which reflects individual owners needs the process of evaluating incremental first costs, along with the costs of owning and operating the various alternatives. These methods range from a simple payback calculation to much more sophisticated life cycle cost (or its equivalent net present value) analysis, or internal rate of return computations.

Each of these factors may vary according to the individual project. Typically, economic analyses are best performed using a computer model or program specifically designed for this purpose.

2.5.1 Critical Parameters

Critical parameters for fair comparisons call for a number of input assumptions. Some of the data may be readily available, some not so available. As many of the following factors as possible should be considered in conducting a proper evaluation:

1. Electric, steam and fuel rate schedules, including demand and energy charges segregated by applicable seasonal or time-of-use criteria and appropriate fuel adjustment charges.
2. Chiller type, size and full load efficiency: for electric chillers consider the kW per ton; for natural gas fueled check the Btu per ton-hour, or the steam pressure at the unit for steam chillers.
3. Consider the size cooling tower required rejecting the building's heat plus the work added to do the cooling that ends up in the chiller's condenser.
4. The chiller unit electric auxiliaries: for electric chillers these are included in the kW per ton; for non-electric chillers this kW per ton should include all the solution, refrigerant, jacket water, lube oil or other pumps (as applicable) and the control power.
5. The chiller system electric auxiliaries in kW per ton These include the condenser water pumps and the cooling tower fans plus any added fans or other power use's applicable to one type chiller but not another.
6. The costs (per 1,000 gallons) to acquire makeup water for the cooling tower, to chemically or otherwise treat this water, and to dispose of the tower overflow and the blow down needed to maintain an acceptable concentration of dissolved solids.
7. The projected annual operating hours of the chiller and the load profile it is designed to serve. For detailed analyses, the chiller's operating schedule including the utilities seasonal and on-peak time definitions must be taken into account. For less detail analyses, the concept of Equivalent Full Load Hours and Integrated Part Load Value can be used.

Several of these key parameters may require further definition. The issues of chiller efficiency, EFLH, IPLV, and APLV are addressed here.

2.5.2 Chiller Efficiency

Chiller operating efficiency is the major component in the annual energy cost. In the past energy was cheap and plentiful, and efficiency received little attention. Older chillers can be quite inefficient. In fact, some chiller replacements will payback quite quickly just due to significantly reduced operating cost at the higher efficiency of the new unit. For analysis purposes, chillers are typically compared on the basis of their ARI Standard Rating - Water cooled, using 44°F leaving chilled water and 85°F inlet condenser water.

All chillers require electric power to operate their auxiliaries (solution, refrigerant, and lube pumps, controls, and so on). These energy costs must be included in the economic comparison, as well as the cost of water required for the cooling tower. The chilled water pump consumption of electricity is common to all chillers, so this power input can be either included or omitted since it almost never affects the outcome of the analysis.

The typical BTU per ton heat rejection for electric chillers is calculated:

(kW/ton-hr x 3,413 Btuh/kW x 0.92) + 12,000 Btuh/ton

where the 0.92 factor makes an 8% allowance for the losses to ambient.

	Steam input	HHV input	Heat rejection	
	at Nom. psig	Btu/ton-hr	Btu/ton-hr	Temp.Diff.
Absorption				
1 stage steam	18 pph	22,000	29,000	15°F
2 stage steam	10 pph	12,200	22,300	10°F
Exhaust Gas Fired (EG)	Varies with EG temp.*		22,900	10°F
Direct Fired	NA	12,000	22,900	10°F
Natural Gas Engine Driven Compressor				
Reciprocating	NA	9,300	16,900	10°F
Rotary Screw	NA	8,600	16,500	10°F
Centrifugal	NA	7,760	16,300	10°F

Table 2.1 Heat-Driven Chiller

Tons Cooling = pph EG flow x (EG temp. - 375) / 40,950

The heat rejection values shown represent the approximate amount of heat that must be rejected to the atmosphere by the cooling tower. This value includes the 12,000 Btu per ton hour of cooling plus the Btu per ton-hour of energy input to the chiller, less an allowance for motor, drive, and radiation losses.

Water-cooled Chiller	Cooling Tower Fans kW/ton	Condenser Water Pump* kW/ton
Reciprocating	.083	.057
Centrifugal	.079	.048
Absorption 1-stage steam	.138	.110
Absorption 2-stage (all models)	.113	.096
Natural Gas Engine	.087	.054

Table 2.2 Cooling Tower Fans & Pumps

These figures are based on efficiencies of 0.70 pumps and 0.90 motor. Condenser fan power is typically included in chiller rated input kW in packaged air-cooled units. If data is not available, estimate it at 0.128 kW/ton.

Chiller Type	Gallons per ton
Electric Chillers	4.0
Absorption 1-stage	8.0
Absorption 2-stage	6.2
Natural gas-driven	4.3

Table 2.3 Typical Chiller System Makeup Water Operating Cost Parameters

	Added kW/ton		
Nat. Gas-Engine Driven	Recip. Compr.	Screw Compr.	Centrifugal Compr.
	0.040	0.033	0.014
Absorption	1-Stage Steam	2-Stage Steam	Direct-Fired
	0.014	0.021	0.024

Table 2.4 Typical Chiller Unit Auxiliaries

2.5.3 Running Hours

The term Running Hours refers to the number of hours a year the chiller operates to meet the indoor design conditions. This usually refers to the number of hours cooling is required over the course of a year while the building is occupied or the enterprise is otherwise in use. The chiller auxiliaries plus the condenser water pump and tower fan will normally operate this number of hours. These hours vary by building type and geographical location.

2.5.4 Equivalent Full Load Hours

Equivalent Full Load Hours (EFLH): Even though a chiller is selected to supply the design load (100% or full load), it does not operate at full load for very many hours out of the year. For example many chillers operate for three quarters of each cooling season at 60% or less of design capacity. A chiller's part load efficiency has a significant effect on operating costs.

EFLH is defined as the annual ton-hours of cooling actually supplied divided by the supplying chiller's design capacity in tons. Using EFLH for analysis purposes is valid where the chiller plant has published continuous, performance values for energy input at all operating levels of output. Normally most centrifugal, screw, and absorption chillers fit this operating profile. However, reciprocating compressor chillers do not have this continuous performance characteristic, due to their step capacity operation and lower efficiency at part load. Therefore, their EFLH must be calculated using a more detailed procedure.

The load calculations for most buildings are performed using a personal computer. These calculations normally establish the running hours per year and enable the designer to estimate a building load profile. A sample annual load profile might look like this:

Annual Load Profile Percent load	**Percent running Hrs**
90% to 100%	2%
81% to 90%	3
71% to 80%	5
61% to 70%	15
51% to 60%	30
41% to 50%	20
31% to 40%	15
21% to 30%	5
11% to 20%	2
0 to 10%	100%

Table 2.5 Equivalent Full Load Hours

The expected EFLH can be projected using a buildings estimated load profile and total annual running hours. For example, using this load profile and an assumed 2,300 running hours, the EFLH can be calculated to be 1,277. If this chiller had a design capacity of 500 tons, it would deliver an estimated 638,500 ton-hrs of cooling (500 tons x 1,277 Equivalent Full Load Hours). PC-based energy analysis tools, including EPRI's COMTECH and APOGEE's chiller screening program, can perform this type of analysis very handily.

2.5.5 Operating Hours and EFLH

Chillers do not normally operate every hour of the year, and may not always operate when the building is occupied. There are days when outside air alone can supply the necessary cooling, and most chillers will require some periodic maintenance during the year even when the chiller could be running (where cooling would be supplied by other equipment during this period). For example, office buildings in the northern climates might call for a chiller to operate 1,000 hours a year while chillers in buildings along the Gulf Coast probably operate more than half the time the building is open. In very humid areas, chillers may have to operate even when the building is unoccupied just to maintain humidity levels. On the other hand, hospital operating rooms often require chiller operation every month of the year (although not necessarily every day). Obviously then, a chiller does not always operate at full load. If the chiller were to meet the annual cooling load by operating only at full load and then cycling off, it would end up operating fewer annual hours. These are defined as Effective Full Load Hours (EFLH) and typically make up about half of the annual operating hours. Therefore, a building that might operate a chiller for 2000 hours in colder climates for general space conditioning should typically expect about 1000 EFLH for that chiller.

CHAPTER THREE
METHODOLOGY

3.1 Design Considerations

The goal of an air-conditioning system is to provide a healthy, comfortable, manufactured indoor environment at acceptable indoor air quality, keeping the system energy efficient. Various occupancies have their own requirements for their indoor environment.

The term air-conditioning is used to describe systems ranging from simple ventilator fans to elaborate apparatus capable of providing an internal atmosphere with air filtered, humidified or de-humidified, heated or cooled, and controlled to accurate limits in each respect. In general, full air-conditioning techniques are found more in industrial and large commercial premises than in domestic premises where the provision is usually a small ventilating unit mounted in a kitchen window pane to extract cooking fumes and heat. With a ducted-air system of heating, the fan motor installed in a house can usually be run during the summer months (with the heating system closed down) to assist in the circulation of air throughout the house and so offer comfortable conditions when the external temperature tends to be high.

There are two main ways in which air-conditioning may be applied. First there is the small unit air conditioner, which consists of a small box containing a refrigerating compressor with cooling coil, a fan, a simple filter and sometimes a heater battery for use in the winter months. Then there is the centralised air-conditioning system which consists of a much larger and more elaborate set of air-treatment equipment installed in a plant chamber from which systems of ducting lead to and from the various parts of the building being served.

Small unit conditioners are common for cooling the rooms of buildings erected before air-conditioning was little more than a motorized fan mounted on the ceiling. They can be readily installed in windows without much structural upheaval.

For industtial applications in this country, the centralized system is common; its main function is to provide special atmospheric conditions of cleanliness, humidity or temperature to ensure uniformity of manufacture.

The common domestic ventilating fan is most often mounted in a window pane, though wall mounted units are also available. The size of fan unit must be correct for a particular application, and is based both on the size of the room and the rate of air change required. This latter factor depends on the situation. A living room requires a recommended minimum of five air changes per hour; a bathroom requires ten; and a boiler house requires twenty-five. The capacity of a ventilating unit is expressed in the number of cubic meters of air per hour moved. This figure is obtained by multiplying the volume of the room by the recommended number of air changes per hour.

Ventilator units can be used to extract air from a room (air removal) or to supply air to it. Many units are provided with reversible control and speed variation; some have automatic shutters which prevent back-draught through the unit when it is not operating. To be effective, these units should be positioned correctly so that cross ventilation is available. Also the units should move the air in every part of a room and particularly where there is a likelihood of stagnant air pockets being unaffected by the unit.

Clean air is generally provided by air filters, some of which are of the electrostatic type which operate on the principle of charging impurities in the air so that they collect on oppositely-charged metal plates in the filter unit.

The basic considerations to select an air-conditioning system include:

1. The selection of an air-conditioning system must satisfy the required space temperature, relative humidity, air cleanliness, sound level, and pressurization. For a Class 100 clean room, a single zone CV clean room system is always selected. A four-pipe fan-coil space conditioning system is usually considered suitable for guest rooms in hotels for operative convenience, better privacy, and a guaranteed outdoor ventilation air system. A concert hall needs a very quiet single-zone VAV central system for its main hall and balcony.

2. The size of the project has a considerable influence on the selection. For a small-size residential air-conditioning system, a single-zone constant volume packaged system is often the first choice.
3. Energy-efficient measures are specified by local codes. Comparison of alternatives by annual energy-use computer programs for medium and large projects is often necessary. Selection of energy source includes electricity or gas, and also using electrical energy at off-peak hours, like thermal storage systems is important to achieve minimum energy cost. For a building whose sound level requirement is not critical and conditioned space is comprised of both perimeter and interior zones, a WSHP system incorporating heat recovery is especially suitable for energy saving.
4. First cost or investment is another critical factor that often determines the selection.
5. Selection of an air-conditioning system is the result of synthetically assessment. It is difficult to combine the effect of comfort, reliability, safety, and cost. Experience and detailed computer program comparisons are both important.

The selection procedure usually begins whether an individual, space conditioning, packaged, central system, or CV, VAV, VAV reheat, fan-powered VAV, dual-duct VAV, or thermal storage system is selected.

Then the air, refrigeration, heating, and control subsystems will be determined. After that, choose the option, the feature, the construction, etc. in each subsystem

Building	SYSTEMS(1) A	B	C	D	E(2)	F(3)	G	H	I(3)
Administration	X	X	X	X	X	X	X	X	X
Apt. Houses	-	-	X	-	-	X	X	X	
Auditoriums	X	X	X	X	-	X	-	X	X
Bachelor Quarters	X	X	X	X	X	X	X	X	X
Bakeries	X	X	X	X	-	-	-	X	X
chapels	X	X	X	X	-	X	X	X	X
Communications	X	X	X	X	-	X	X	X	X
Family Housing	X	-	X	-	-	X	X	X	X
Gymnasiums	X	-	-	-	-	-	-	-	X
Hangar	-	-	-	-	-	X	X	-	X
Hospitals	X	X	X	X	-	X	X	X	X
Laundries	X	X	X	X	-	-	-	X	X
Schools	X	X	X	X	-	X	X	X	X
Shops	X	X	X	X	-	X	-	-	X
Theaters	X	X	X	X	-	X	-	-	X
Transmitters	X	X	X	X	-	X	-	-	X
Warehouses	X	-	X	-	-	-	-	-	X

Table 3.1 Recommended Air conditioning Systems for Various Buildings

NOTES:

1. System Types:
   - A. single Duct System
   - B. Dual Duct System
   - C. Multi-zone System
   - D. Variable Air Volume System
   - E. Perimeter Zone Air system
   - F. Fan Coil System
   - G. Induction System
   - H. Heat Pump System
   - I. Evaporated Cooling System
2. Depends on building configuration
3. Depends on local weather conditions

Central systems use chilled and hot water that comes from the central plant to cool and heat the air in the air-handling units (AHUs). Central systems are built-up systems. The most clean, most quiet thermal storage systems, and the systems which offer the most sophisticated features, are always central systems.

3.2 Load Calculation Methodology

Before calculating heat loads we may go through some expressions like Space, Room, Zone, Load Profile, Peak Load, and Block Load.

Space indicates a volume or a site without partitions, or a partitioned room or a group of rooms. A room is an enclosed or partitioned space that is considered as a single load. An air-conditioned room does not always have an individual zone control system. A zone is a space of a single room or group of rooms having similar loads and operating characteristics. An air-conditioned zone is always installed with an individual control system. A typical floor in a building may be treated as a single zone space, or a multi zone space of perimeter, interior, east, west, south, and north... zones.

A load profile shows the variation of space, zone, floor, or building load in a certain time period, such as a 24-hr day-and-night cycle. In a load profile, load is always plotted against time. The load profile depends on the outdoor climate as well as the space operating characteristics.

Peak load is the maximum cooling load in a load profile. Block load is the sum of the zone loads and floor loads at a specific time. The sum of the zone peak loads in a typical floor does not equal the block load of that floor because the zone peak loads may all not appear at the same time.

Heat enters a space and transfer to the space air from either an external source or an internal source is mainly in the form of convective heat and radiative heat transfer.

Consider radiative heat transfer, such as solar radiation striking the outer surface of a concrete slab as shown in figure below.

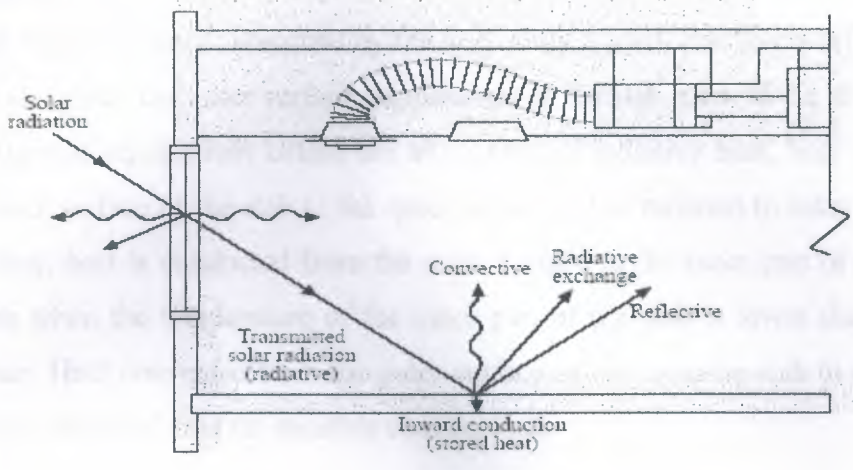


Figure 3.1(a) Convective and radiative heat transfer

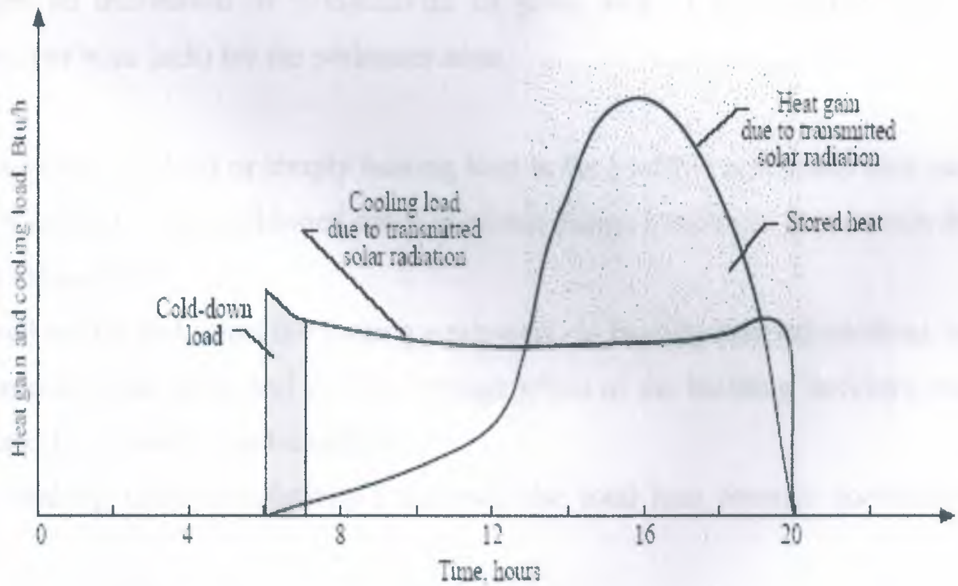


Figure 3.1(b) Heat gain and cooling load curves.

Solar heat gain from west window and its corresponding space cooling load for a night shutdown air system: (a) convective and radiative heat transfer and (b) heat gain and cooling load curves.

Most of the radiative heat is absorbed by the slab. Only a small fraction is reflected. After the heat is absorbed, the outer surface temperature of the slab rises. If the slab and space air are in thermal equilibrium before the absorption of radiative heat, heat is convected from the outer surface of the slab to the space air as well as radiated to other surfaces. At the same time, heat is conducted from the outer surface to the inner part of the slab and stored there when the temperature of the inner part of the slab is lower than that of its outer surface. Heat convected from the outer surface of the concrete slab to the space air within a time interval forms the sensible cooling load.

Infiltration is the uncontrolled inward flow of unconditioned outdoor air through cracks and openings on the building envelope because of the pressure difference across the envelope. The pressure difference is probably caused by wind pressure, stack effect due to outdoor–indoor temperature difference, and the operation of an air system(s). For hotels, motels, and high-rise residential buildings, ASHRAE/IES Standard 90.1-1989 specifies an infiltration of 0.038cfm/ft2 of gross area of the external wall, 0.15 air changes per hour (ach) for the perimeter zone.

The space heating load or simply heating load is the possible maximum heat energy that must be added to the conditioned space at winter design conditions to maintain the indoor design temperature.

It is used to size and select the heating equipment. In heating load calculations, solar heat gain, internal heat gains, and the heat storage effect of the building envelope are usually neglected for reliability and simplicity.

While making these calculations I followed the total heat transfer coefficients tables below:

Horizontal Brick	W-1	1.3
Vertical double brick with air gap	W-2	1.1
Vertical double brick with isolation	W-3	0.9
Ytong	W-4	0.7

Table 3.2(a) Walls covered with plaster on both sides

Wooden single glazed	Wood-SG	4.5
Wooden double glazed	Wood-DG	2.8
Metal single glazed	Metal-SG	5.0
Metal double glazed	Metal-DG	3.4
PVC single glazed	PVC-SG	4.3
PVC double glazed	PVC-DG	2.2
Wooden door		3.0

Table 3.2 (b) Windows – Doors

Floor	1.8
Roof	2.0

Table3.2(c) Floors & Roofs

Total Heat Transfer Coefficients Ikcal/h-m2

CHAPTER FOUR
RESULTS

ELECTRICAL INSTALLATION

4.1 Control Circuits

4.1.1 Wye-Delta Starters

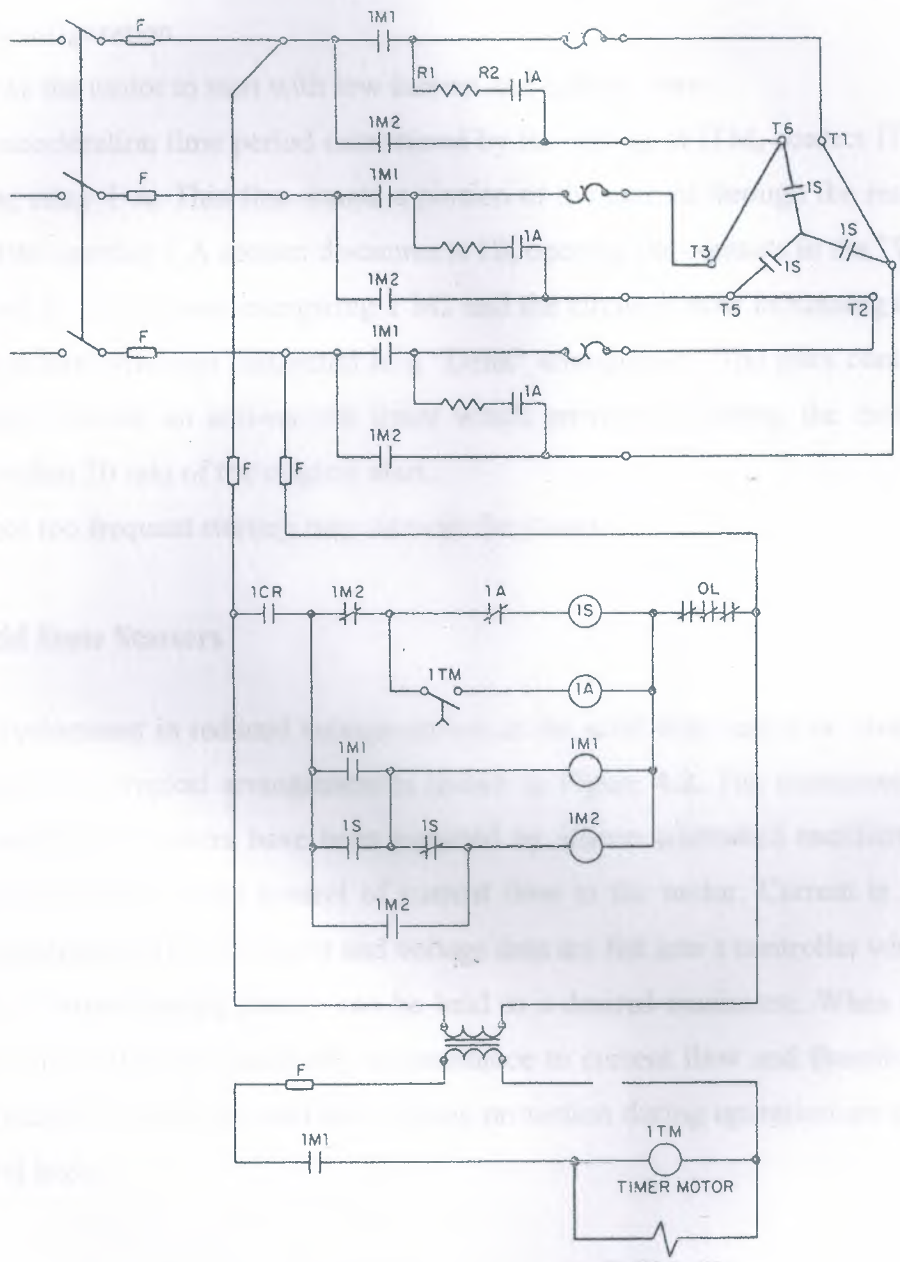


Figure 4.1 Wye-Delta Starter

Wye-Delta starters require specially wound motors, but have excellent starting characteristics, especially with very large motors. They are available with both open- and closed-transition arrangements.

A pilot control circuit (not shown) activates control relay 1 CR. Contact 1 CR closes and energizes relay 1S. This in turn energizes 1 M 1 and the motor windings are energized in a "Wye" configuration.
This allows the motor to start with low current and voltage draw.
After an acceleration time period determined by the setting of lTM, contact lTM closes, energizing relay 1 A. This first shunts a portion of the current through the resistors and then the late-opening 1 A contact disconnects 1S, opening the contacts in the "Wye." The NC contact in 1S re-closes energizing 1 M2 and the circuit is now in running configuration with motor windings connected in a "Delta" arrangement. The pilot control circuit will usually include an anti-recycle timer which prevents restarting the motor if it is stopped within 20 min of the original start.

Note that too frequent starting may damage the starter.

4.1.2 Solid State Starters

A new development in reduced voltage starters is the solid state starter or what so called “soft starters”. A typical arrangement is shown in Figure 4.2. The contactors found in electro-mechanical starters have been replaced by silicon controlled rectifiers (SCR's), which provide proportional control of current flow to the motor. Current is sensed by current transformers (CT). Current and voltage data are fed into a controller which drives the SCR's. Current during startup can be held to a desired maximum. When the SCR's are fully “on" they offer essentially no resistance to current flow and therefore act like closed contacts. Overcurrent and low-voltage protection during operation are inherent in the control logic.

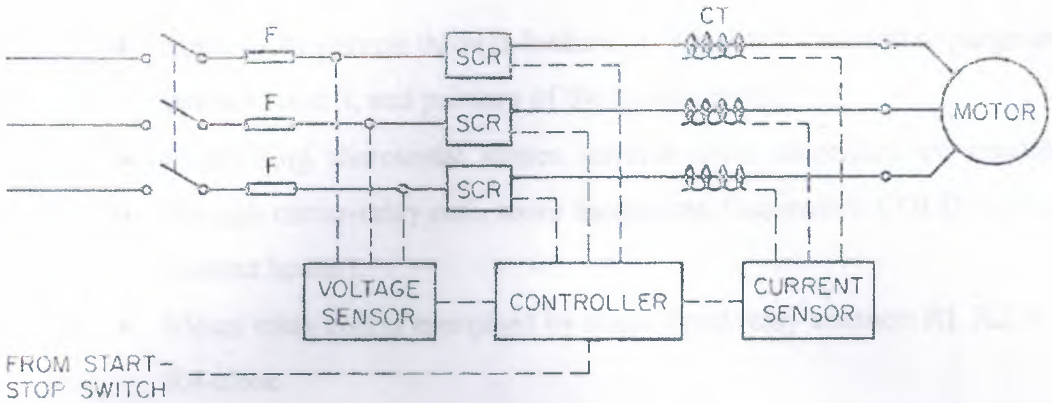


Figure 4.2 Solid state starter

4.1.3 Oil-burner Automatic Control Circuit

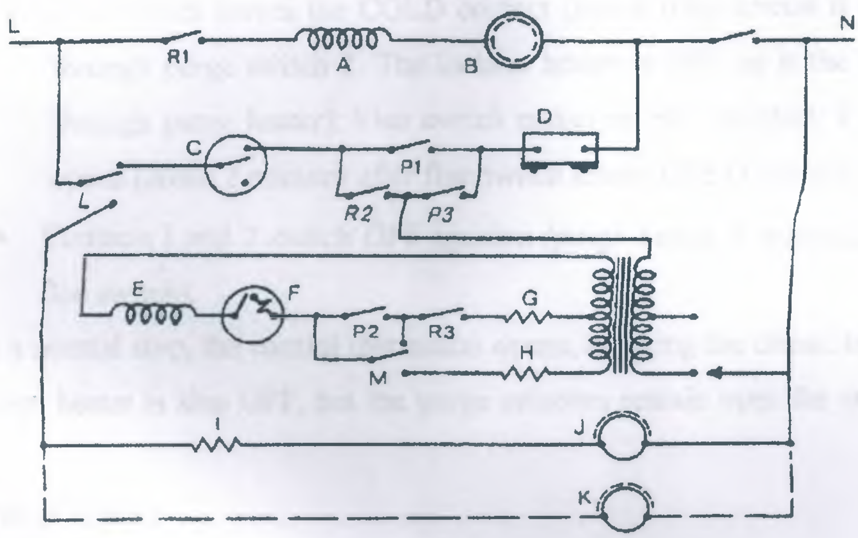


Figure 4.3 Oil-burner Automatic Control Circuit

In the above circuit R1, R2, R3 are relay switches; PI, P2, P3 are purge switches; A is a de-magnetize relay coil; B is a burner motor; C is a limit control; D is an ignition transformer; E is a relay coil; F is a room thermostat; G is a purge heater; H is a lockout heater; I is a lamp resistance; J is a lock-out lamp; K is remote alarm; L is a lock-out switch; M is a flue switch.

The equipment is assumed to be in the ready-to-start condition.

The starting sequence is as follows:

- Supply ON (circuit through lockout switch, limit thermostat, purge-switch contact I and 3, and primary of the transformer).
- Controlling thermostat closes (circuit from secondary of transformer through motor-relay coil, room thermostat, flue-switch COLD contact and lockout heater).
- Motor relay coil is energized by stage 2 and relay contacts RI, R2, R3 and R4-close.
- Motor starts.
- Ignition transformer energized.
- Lockout heater energized.
- Oil ignites
- Flue switch leaves the COLD contact (motor relay circuit is maintained through purge switch 2. The lockout heater is OFF, as is the full current through purge heater); Flue switch makes on HOT contact; Purge switch opens (about 2 minutes after flue switch leaves COLD contact);
- Contacts I and 2 switch OFF ignition (purge heater is maintained by the flue switch).

Note that in a normal stop, the control thermostat opens, breaking the circuit to the relay coil. The purge heater is also OFF, but the purge switches remain open for at least two minutes.

4.1.4 Control of Chiller

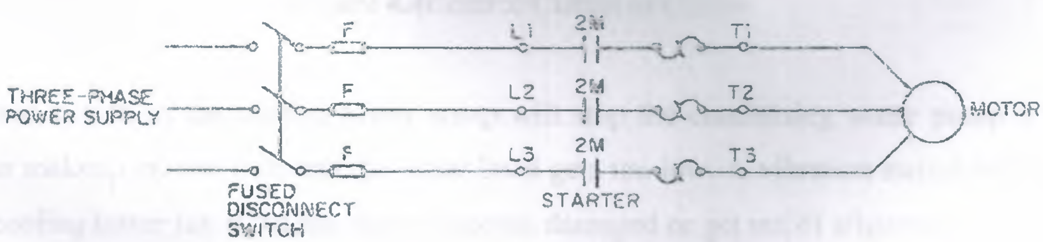
To illustrate a relatively simple and basic interlock system consider the diagram in Figure 4.4. Here are shown a water chiller, a compressor, a circulating chilled water pump, a condensing water pump, a cooling tower fan and the necessary relays and safety controls. The power for the control circuit is obtained from a control transformer in the compressor starter, since this is the critical piece of apparatus. To place the system in operation the chilled water pump is started manually by means of a "start" push button. As the water flows in the system, its temperature leaving the chiller is measured by a two-position thermostat. When the water temperature is above the thermostat setting, the thermostat contact closes, opening the solenoid valve, in the refrigerant liquid line to the evaporator. The resulting rise in the suction pressure will close the low-pressure switch, starting the condensing water pump. If water is flowing in both chilled and condensing water circuits (flow switches closed) and all safety controls are closed, then the compressor motor will start.

The cooling tower fan is started, and stopped by a thermostat in the condensing water supply, so that the condensing water will not get too hot or too cold.

When the chilled water thermostat is satisfied, its contacts will open, closing the solenoid valve, but the condensing pump and compressor will continue to run until the system "pumps down," that is, until the decreasing, suction pressure opens the low-pressure switch. This "pump down" cycle is accomplished by the pump down relay (1 CR).

Numerous safety controls are provided to protect the equipment against operating under adverse and potentially damaging conditions. The oil pressure switch contains a heater-which is energized when the compressor starts. It is necessary for increasing oil pressure to open a pressure switch in the heater circuit it before the heater opens a thermally delayed contact in the compressor starter circuit.

The compressor may also be stopped by too high a condensing pressure, too Iowa suction pressure, high refrigerant temperature, low chilled water fj temperature or inadequate flow of chilled or condensing water; or, of course, by the thermal overloads in the motor starter.



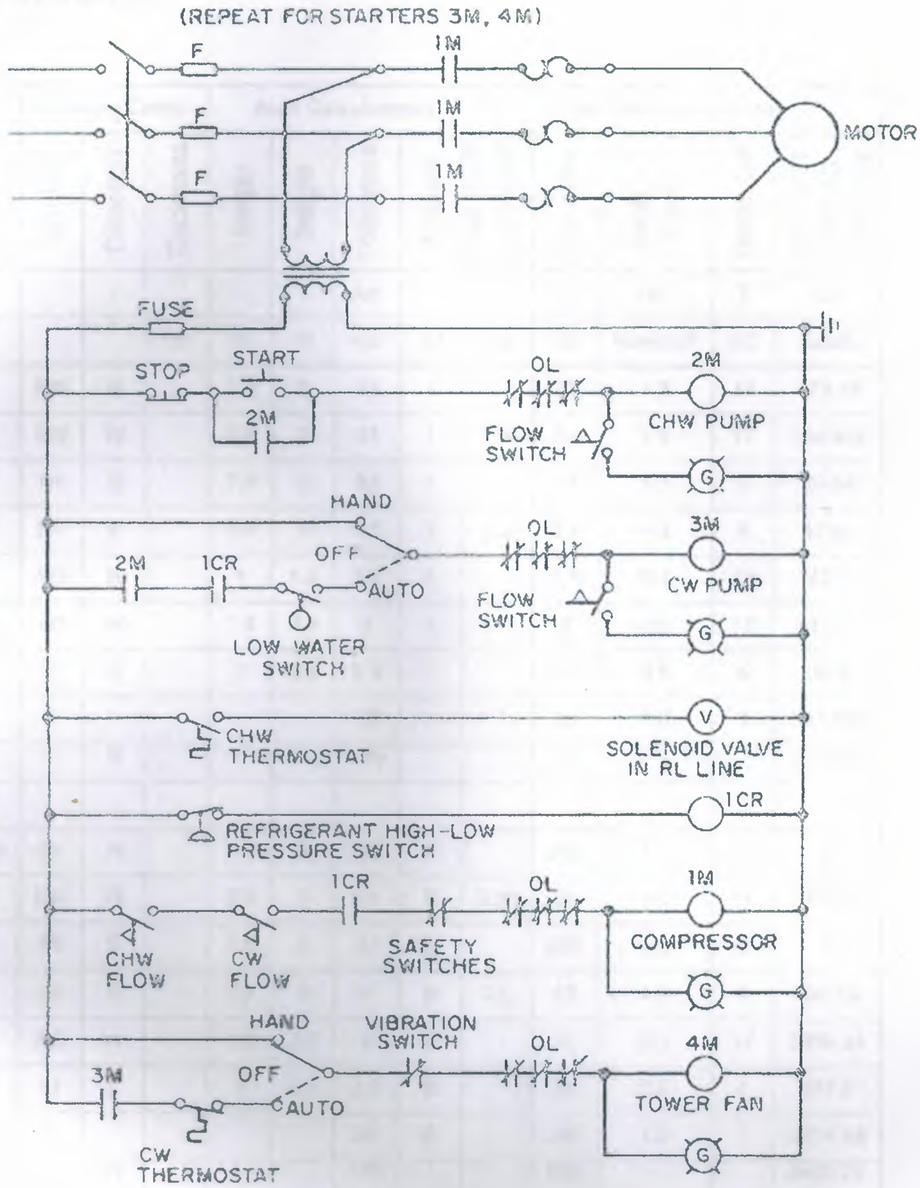


Figure 4.4 Control Circuit of Chiller

A float switch in the cooling tower sump will stop the condensing water pump if the water makeup system fails and the water level gets too low. A vibration switch will stop the cooling tower fan if the fan blades become damaged or get out of alignment.

The control system just described contains a number of conventional symbols for various types of operating and safety switches. These and many other standard symbols for electrical devices are in common use.

4.2 Heat Loss Calculations

	Building Comp			Area Calculations					Heat loss Calculations			
Room No.	symbol	Direction	Thickness	length	height	Total area	Amount	Area to be subtracted	Net area	Heat tr. Coeff.	Temp. Diff	Heat loss Without additions
						Ao				k	T	Qo
			cm	m	m	m2	Ad	m2	m2	kcal/m2h	oC	kcal/h
1	EW	N		7.6	3	23	1	1.3	22	1.3	17	475.15
	EW	W		3.8	3	11	1	3.96	7.4	1.3	17	164.424
	IW	S		7.6	3	23	1		23	1.3	1	29.64
	IW	E		3.8	3	11	1	2.2	9.2	1.3	4	47.84
	SG	N		1	1.3	1.3	1		1.3	6.5	17	143.65
	SG	W		1.8	2.2	4	1		4	6.5	17	437.58
	ID	E		1	2.2	2.2	1		2.2	3.5	4	30.8
	F					29	1		29	1.8	7	363.888
Total		N				105			97			1692.97
2_10	IW	N		7.6	3	23	9		205	1.3	0	0
	EW	W		3.8	3	11	9	3.96	67	1.3	17	1479.82
	IW	S		7.6	3	23	9		205	1.3	0	0
	IW	E		3.8	3	11	9	2.2	83	1.3	4	430.56
	SG	W		1.8	2.2	4	9		36	6.5	17	3938.22
	ID	E		1	2.2	2.2	9		20	3.5	4	277.2
	F					29	9		260	1.8	7	3274.99
Total		W				103			876			9400.79
11	EW	s		7.6	3	23	1		23	1.3	17	503.88
	EW	W		3.8	3	11	1	3.96	7.4	1.3	17	164.424
	IW	E		1.8	2.2	4	1	2.2	1.8	1.3	4	9.152
	SG	W		1.8	2.2	4	1		4	6.3	17	424.116
	ID	E		1	2.2	2.2	1		2.2	3.5	4	30.8
	F					29	1		29	1.8	7	365.4
Total		S				73			67			1497.77
12	EW	N		7.6	3	23	1	1.3	22	1.3	17	475.15
	EW	W		3.8	3	11	1	3.96	7.4	1.3	17	164.424
	IW	S		7.6	3	23	1		23	1.3	1	29.64

		IW	E		3.8	3	11	1	2.2	9.2	1.3	4	47.84
		SG	N		1	1.3	1.3	1		1.3	6.5	17	143.65
		SG	W		1.8	2.2	4	1		4	6.5	17	437.58
		ID	E		1	2.2	2.2	1		2.2	3.5	4	30.8
		R					29	1		29	2	15	866.4
Total			N				105			97			2195.48
	13-21	IW	N		7.6	3	23	9		205	1.3	0	0
		EW	W		3.8	3	11	9	3.96	67	1.3	17	1479.82
		IW	S		7.6	3	23	9		205	1.3	0	0
		IW	E		3.8	3	11	9	2.2	83	1.3	4	430.56
		SG	W		1.8	2.2	4	9		36	6.5	17	3938.22
		ID	E		1	2.2	2.2	9		20	3.5	4	277.2
		R					29	9		260	2	17	8837.28
Total			W				103			876			14963.1
	22	EW	s		7.6	3	23	1		23	1.3	17	503.88
		EW	W		3.8	3	11	1	3.96	7.4	1.3	17	164.424
		IW	E		1.8	2.2	4	1	2.2	1.8	1.3	4	9.152
		SG	W		1.8	2.2	4	1		4	6.3	17	424.116
		ID	E		1	2.2	2.2	1		2.2	3.5	4	30.8
		R					29	1		29	2	17	986
Total			S				44			38			2118.37

	Additions					Infiltration							
Room No.	Comp.	Floor Height	Direction	Total	Total heat required	Infiltration coefficient	Periphery	Room coefficient	Building coefficient		Heat for Infiltration	Total heat loss	Pkkp 600 length
	ZD	ZW	ZH	Z		a	l	R	H	Ze	Qs	Q	L
	%	%	%	1+%	kcal/h		m				kcal/h	kcal/h	Cm
1				1	475.2						0	475.15	
				1	164.4						0	164.42	
				1	29.64						0	29.64	
				1	47.84						0	47.84	
				1	143.7	2	5	0.7	0.58	1	63.5	207.1	

													5	
					1	437.6	2	10	0.7	0.58	1	135.3	572.86	
					1	30.8	2	6	0.7	0.58	1	20.79	51.587	
		0.808			1	363.9						0	363.89	
Total		0.2	0	0.05	1.3	3809						219.6	4028.8	174.3
	2_10				1	0						0	0	
					1	1480						0	1479.8	
					1	0						0	0	
					1	430.6						0	430.56	
					1	3938	2	10	0.9	0.58	1	173.9	4112.2	
					1	277.2	2	6	0.9	0.58	1	26.73	303.93	
		0.505			1	3275						0	3275	
Total		0.25	0	0	1.3	21152						200.7	21352	923.5
	11				1	503.9						0	503.88	
					1	164.4						0	164.42	
					1	9.152						0	9.152	
					1	424.1	2	10	0.9	0.58	1	173.9	598.05	
					1	30.8	2	6	0.9	0.58	1	26.73	57.526	
		1.021			1	365.4						0	365.4	
Total		0.2	0	-0.05	1.2	3220						200.7	3420.9	148
	12				1	475.2						0	475.15	
					1	164.4						0	164.42	
					1	29.64						0	29.64	
					1	47.84						0	47.84	
					1	143.7	2	5	0.7	0.58	1	63.5	207.15	

					1	437.6	2	10	0.7	0.58	1	135.3	572.86	
					1	30.8	2	6	0.7	0.58	1	20.79	51.587	
		1.048			1	866.4						0	866.4	
Total		0.2	0	0.05	1.3	4940						219.6	5159.4	223.2
	13-21				1	0						0	0	
					1	1480						0	1479.8	
					1	0						0	0	
					1	430.6						0	430.56	
					1	3938	2	10	0.9	0.58	1	173.9	4112.2	
					1	277.2	2	6	0.9	0.58	1	26.73	303.93	
		0.804			1	8837						0	8837.3	
Total		0.2	0	0	1.2	32919						200.7	33119	1433
	22				1	503.9						0	503.88	
					1	164.4						0	164.42	
					1	9.152						0	9.152	
					1	424.1	2	10	0.9	0.58	1	173.9	598.05	
					1	30.8	2	6	0.9	0.58	1	26.73	57.526	
		2.39			1	986						0	986	
Total		0.15	0	-0.05	1.1	4449						200.7	4649.2	201.1

Total Heat Loss=71730

R1				8:00	12:00	16:00	8:00	12:00	16:00	Formula
Radiation through windows										
Direction		Area (m2)			Qrad (watt)		Unit heat gain (Watt/m2			
E				0	0	0	50	50	500	Area*Unit heat gain
W		4		2000	200	200	500	50	50	

S				0	0	0	50	200	50	
N		1.3		65	65	65	50	50	50	
NE				0	0	0	350	50	50	
SE				0	0	0	350	150	50	
SW				0	0	0	50	150	350	
NW				0	0	0	50	50	350	
Radiation through roof										
	K(W/m2 K)	Area (m2)	isolation		Qrad (watt)		Equivalent Temp. Diff.			
Sunny	2.2			0	0	0	5	10	22	K*Area*Eq.Temp.Diff
Shadow	2.2	29	1	0	255.2	446.6	0	4	7	Teq*Teq*Isolation
isolated: 0,75 , Not isolated: 1										
Convection through walls										
Direction	K(W/m2 K)	Area (m2)			Qrad (watt)		Equivalent Temp. Diff.			
NE	1.6			0	0	0	10	10	10	K*Area*Eq.Temp.Diff
E	1.6	11		176	352	176	10	20	10	
SE	2.9			0	0	0	5	15	10	
S	2.9	23		0	667	1000.5		10	15	
SW	2.9			0	0	0			20	
W	1.6	7.4		0	0	236.8			20	
NW	1.6			0	0	0			15	
N	1.6	22		0	0	352			10	
K=2,9 for S, SW, SE. K=1,6 for others										
Convection through windows										
	K(W/m2 K)	Area (m2)			Qrad (watt)		Equivalent Temp. Diff.			
Wood SG	5.25	5.3		333.9	333.9	333.9	12	12	12	K*Area*Eq.Temp.Diff
Wood DG	3.25			0	0	0	12	12	12	
Metal SG	5.8			0	0	0	12	12	12	
Metal	4			0	0	0	12	12	12	

DG										
Heat gain due to person										
	Heat(W/per)	Number			Qrad (watt)					
Person	130	2		260	260	260				Heat*No
Heat gain due to lightening										
	Heat(W/m2)	Area (m2)			Qrad (watt)					
Lightening	10	29		290	290	290				Heat*Area
TOTAL COOLİNG CAPACİTY (W)				3124.9	2423.1	3360.8				
TOTAL COOLİNG CAPACİTY (Btu/h)				10662.2	8267.62	11467				

R2-R11				**8:00**	**12:00**	**16:00**	**8:00**	**12:00**	**16:00**	**Formula**
Radiation through windows										
Direction		Area (m2)			Qrad (watt)		Unit heat gain (Watt/m2			
E				0	0	0	50	50	500	Area*Unit heat gain
W		4		2000	200	200	500	50	50	
S				0	0	0	50	200	50	
N				0	0	0	50	50	50	
NE				0	0	0	350	50	50	
SE				0	0	0	350	150	50	
SW				0	0	0	50	150	350	
NW				0	0	0	50	50	350	
Radiation through roof										
	K(W/m2K)	Area (m2)	isolation		Qrad (watt)		Equivalent Temp. Diff.			
Sunny	2.2			0	0	0	5	10	22	K*Area*Eq. Temp.Diff
Shadow	2.2	29	1	0	255.2	446.6	0	4	7	Teq*Teq* Isolation
isolated: 0,75 , Not isolated: 1										

Convection through walls

Direction	K(W/m2K)	Area (m2)			Qrad (watt)		Equivalent Temp. Diff.			
NE	1.6			0	0	0	10	10	10	K*Area*Eq. Temp.Diff
E	1.6	11		176	352	176	10	20	10	
SE	2.9			0	0	0	5	15	10	
S	2.9	23		0	667	1000.5		10	15	
SW	2.9			0	0	0			20	
W	1.6	7.4		0	0	236.8			20	
NW	1.6			0	0	0			15	
N	1.6	23		0	0	368			10	

K=2,9 for S, SW, SE.

K=1,6 for others

Convection through windows

	K(W/m2K)	Area (m2)			Qrad (watt)		Equivalent Temp. Diff.			
Wood SG	5.25	4		252	252	252	12	12	12	K*Area*Eq. Temp.Diff
Wood DG	3.25			0	0	0	12	12	12	
Metal SG	5.8			0	0	0	12	12	12	
Metal DG	4			0	0	0	12	12	12	

Heat gain due to person

	Heat(W/per)	Number			Qrad (watt)					
Person	130	2		260	260	260				Heat*No

Heat gain due to lightening

	Heat(W/m2)	Area (m2)			Qrad (watt)					
Lightening	10	29		290	290	290				Heat*Area

TOTAL COOLİNG CAPACİTY (W)	2978	2276.2	3229.9				
TOTAL COOLİNG CAPACİTY (Btu/h)	10160.936	7766.3944	11020.419				W*3,412

R13-R22			**8:00**	**12:00**	**16:00**	**8:00**	**12:00**	**16:00**	**Formula**
	Area (m2)			Qrad (watt)		Unit heat gain (Watt/m2			
			0	0	0	50	50	500	Area*Unit heat gain
	4		2000	200	200	500	50	50	
			0	0	0	50	200	50	
			0	0	0	50	50	50	
			0	0	0	350	50	50	
			0	0	0	350	150	50	
			0	0	0	50	150	350	
			0	0	0	50	50	350	
K(W/m2 K)	Area (m2)	isolation		Qrad (watt)		Equivalent Temp. Diff.			
2.2	29	1	319	638	1403.6	5	10	22	K*Area*Eq.Temp.Diff
2.2			0	0	0	0	4	7	Teq*Teq*Isolation
K(W/m2 K)	Area (m2)			Qrad (watt)		Equivalent Temp. Diff.			
1.6			0	0	0	10	10	10	K*Area*Eq.Temp.Diff
1.6	11		176	352	176	10	20	10	
2.9			0	0	0	5	15	10	
2.9	23		0	667	1000.5		10	15	
2.9			0	0	0			20	
1.6	7.4		0	0	236.8			20	
1.6			0	0	0			15	
1.6	22		0	0	352			10	
K(W/m2 K)	Area (m2)			Qrad (watt)		Equivalent Temp. Diff.			
5.25	4		252	252	252	12	12	12	K*Area*Eq.Tem

									p.Diff
3.25			0	0	0	12	12	12	
5.8			0	0	0	12	12	12	
4			0	0	0	12	12	12	
Heat(W/ per)	Numbe r			Qrad (watt)					
130	2		260	260	260				Heat*No
Heat(W/ m2)	Area (m2)			Qrad (watt)					
10	29		290	290	290				Heat*Area
			3297	2659	4170.9				
			11249. 364	9072.50 8	14231. 111				W*3,412

R12				8:00	12:00	16:00	8:00	12: 00	16: 00	Formula	
Radiation through windows											
Directi on		Area (m2)			Qrad (watt)		Unit heat gain (Watt/m2				
E				0	0	0	50	50	500	Area*Unit heat gain	
W		4		2000	200	200	500	50	50		
S				0	0	0	50	200	50		
N		1.3		65	65	65	50	50	50		
NE				0	0	0	350	50	50		
SE				0	0	0	350	150	50		
SW				0	0	0	50	150	350		
NW				0	0	0	50	50	350		
Radiation through roof											
	K(W/m2 K)	Area (m2)	isolati on		Qrad (watt)		Equivalent Temp. Diff.				
Sunny	2.2	29	1	319	638	1403. 6	5	10	22	K*Area*Eq.Tem p.Diff	
Shado w	2.2			0	0	0	0	4	7	Teq*Teq*Isolati on	
isolated: 0,75 , Not isolated: 1											

Convection through walls

Direction	K(W/m2 K)	Area (m2)			Qrad (watt)		Equivalent Temp. Diff.			K*Area*Eq.Temp.Diff
NE	1.6			0	0	0	10	10	10	
E	1.6	11		176	352	176	10	20	10	
SE	2.9			0	0	0	5	15	10	
S	2.9	23		0	667	1000.5		10	15	
SW	2.9			0	0	0			20	
W	1.6	7.4		0	0	236.8			20	
NW	1.6			0	0	0			15	
N	1.6	22		0	0	352			10	
K=2,9 for S, SW, SE. K=1,6 for others										

Convection through windows

	K(W/m2 K)	Area (m2)			Qrad (watt)		Equivalent Temp. Diff.			K*Area*Eq.Temp.Diff
Wood SG	5.25	5.3		333.9	333.9	333.9	12	12	12	
Wood DG	3.25			0	0	0	12	12	12	
Metal SG	5.8			0	0	0	12	12	12	
Metal DG	4			0	0	0	12	12	12	

Heat gain due to person

	Heat(W/per)	Number			Qrad (watt)					
Person	130	2		260	260	260				Heat*No

Heat gain due to lightening

	Heat(W/m2)	Area (m2)			Qrad (watt)					
Lightening	10	29		290	290	290				Heat*Area

TOTAL COOLİNG CAPACİTY (W)				3443.9	2805.9	4317.8				
TOTAL COOLİNG CAPACİTY (Btu/h)				11750.6	9573.73	14732.3				W*3,412

4.3 Calculation for the outdoor unit

Pipe			Heat	Length (L)	Flow Rate	Flow Rate	Diameter	Velocity	Pressure Drop	Pressure Drop R	LR	∑ζ	Z=LR+∑ζ
No	W		Kcal/h	m	lt/h	lt/s	mm	m/s	Pa/m	mmss/m	mmss	mmss	mmss
1	11467	283727	244005	8	12200	3.389	80	0.7		5.5	44	1.3	114.4
2	11020	272260	234143	5.4	11707	3.252	80	0.6		5	27	1.3	70.2
3	11020	261239	224666	2.7	11233	3.1204	65	0.85		10	27	1.3	70.2
4	11020	250219	215188	5.6	10759	2.9887	65	0.85		10	56	1.3	145.6
5	11020	239199	205711	1.4	10286	2.8571	65	0.8		9	12.6	1.3	32.76
6	11020	228178	196233	5.4	9811.7	2.7255	65	0.75		8	43.2	1.3	112.32
7	11020	217158	186756	2.6	9337.8	2.5938	65	0.7		7	18.2	1.3	47.32
8	11020	206137	177278	5.4	8863.9	2.4622	60	0.8		10	54	1.3	140.4
9	11020	195117	167801	2.6	8390	2.3306	60	0.75		9	23.4	1.3	60.84
10	11020	184097	158323	5.4	7916.1	2.1989	60	0.7		8	43.2	1.3	112.32
11	11020	173076	148845	2.6	7442.3	2.0673	60	0.7		7.5	19.5	1.3	50.7
12	14732	162056	139368	8.2	6968.4	1.9357	60	0.65		6.5	53.3	1.3	138.58
13	14732	147323	126698	2.6	6334.9	1.7597	56	0.75		10	26	1.3	67.6
14	147	1325	1140	5.4	5701	1.58	56	0.6		8	43.2	1.3	112.

	32	91	28		.4	37		5					32
15	14732	117859	101358	2.6	5067.9	1.4078	56	0.6		6.5	16.9	1.3	43.94
16	14732	103126	88689	5.4	4434.4	1.2318	50	0.6		8	43.2	1.3	112.32
17	14732	88394	76019	2.6	3800.9	1.0558	50	0.55		6	15.6	1.3	40.56
18	14732	73662	63349	5.4	3167.5	0.8798	50	0.46		4.5	24.3	1.3	63.18
19	14732	58929	50679	1.4	2534	0.7039	40	0.55		9	12.6	1.3	32.76
20	14732	44197	38009	5.6	1900.5	0.5279	40	0.42		5	28	1.3	72.8
21	14732	29465	25340	2.7	1267	0.3519	32	0.38		5	13.5	1.3	35.1
22	14732	14732	12670	5.4	633.49	0.176	25	0.32		5.5	29.7	1.3	77.22

Total 1753.4

Table 4.1 Load calculations

4.4 Water Pump calculation

- Pressure = "1.753 mss"
- Flow rate = "12.2 m^3/h"
- Speed at the 1st level

  Pressure = "2.7 mss"

  Flow rate = 15 m^3/h
- Speed at the 2nd level

  Pressure = 2 mss

  Flow rate = "12.5 m^3/h"
- Speed at the 3rd level

  Pressure = 1 mss

  Flow rate = 9 m^3/h

4.5 Water expansion tank calculation

- $H_{max.} = 8.9m$
- $P_{air} = 8.9$ mwH = 0.89 bar $P_{safety} = 2.5$ bar
- $P_{max} = P_{safe} - 0.5$ bar = 2 bar $P_o = P_{safe} - P_{air} = 1.61$
- $V_{total} = Q * f = 70.2505 * 8 = 562$ lt
- $\Delta V = V_{total} * (n/100) = 20.37$ lt, n90 = 3.55
- $V_{spare} = V_{total} * (5/1000) = 2.87$ lt
- $V_{nominal} = ((\Delta V + V_{spare}) (P_{max} + 1)) / (P_{max} - \rho_o) = 180$ lt

4.6 Fuel Tank calculation

- Fuel consumption = Q / H = 83406.98 / 10000 = 8.34 kg / h
- Daily fuel consumption = 8.34 * 14 h =116.77 kg / day
- In a week = 116. 77 * 7 = 817.39 kg / week
- In a month = 817.39 * 4 = 3269.6 kg / month
- Fuel tank capacity = 3269.6 / 910 = 3.59 m3

CONCLUSION

After a great deal of working over this project theoretically and practically; I found out how much knowledge I gained and how much techniques I learnt in selecting, designing air conditioning system and preparing electrical installation for that system. I also learnt how to manage and decide alternatives for not available components, to understand the whole air conditioning system.

The proper selection of an air conditioning system requires an understanding of the project needs. That is one of what I gained from this project.

This project consists of four chapters; each chapter presented a specific aspect of air conditioning subject as a working principle, components which it consists of and more.

Chapter two presented sought components in details, how they function and how they must be connected. Also it discussed safety guidelines to prevent possible mistakes that may damage the system.

Chapter three started with the considerations for designing air conditioning system. Then it presented load calculations methodology by discussing heat loss, convection, and radiation calculations.

Chapter four was the most important chapter of this project; it presented the results of load calculations. It also presented explanation of control circuit for system's equipments, the jobs of components and how it must be connected to the circuit to do the work efficiently.

The main guidelines of this project were:

- To design, build and install air conditioning system.
- To gain experience as much as could be with practical installations projects.
- To sort out problems within the control circuits and suggest modifications, to overcome the problems.

REFRENCES

[1] Herrick, C.N., Connolly, K., *Electrical Control Systems for Heating and Air Conditioning*, Prentice Hall, Englewood Cliffs, 1998

[2] Haines, Roger W., *Control System for Heating, Ventilating and Air Conditioning*, Van Nostrand Reihold, NewYork,1987

[3] Allard F., "Natural Ventilation in Buildings – A Design Handbook", James & James (Science Publishers) Ltd, London 1998

[4] *ASHRAE Handbook 1999*, HVAC Applications, SI Edition, Atlanta

[5] *ASHRAE Handbook 2000*, HVAC Systems and Equipment, SI Edition, Atlanta

[6] Lang, P. V., *Basics of air conditioning*, Third edition, Van Nostrand Reinhold Company, 1979.

[7] Down, P. G., *Heating and Cooling load calculations*, Pergamon Press, 1994.

[8] Haines, R. W., Wilson, L. C., *HVAC systems design handbook*, McGraw Hill Inc., 1994.

[9] Pita, E. G., *Air Conditioning principles and systems: An energy approach*, Johnwiley & Sons, 1981.

[10] Wang, K. S., *Handbook of air conditioning and refrigeration*, McGraw Hill Inc., 1994.

[11] Langley, B. C., *Fundamentals of air conditioning systems*, The Fairmont Press Inc., 1995.

[12] Parmley, O. R., *HVAC design data sourcebook*, McGraw-Hill, Inc., 1994.

[13] Cengel, Y. A., *Heat Transfer – A practical Approach*, WCB McGraw-Hill, Inc., 1998.

[14] Kreider, K. F., Rabl, A., *Heating and Cooling of Buildings*, McGraw-Hill, New York, 1994.

[15] McQuiston, F, C., and Parker, J, D., *Heating, Ventilating, and Air Conditioning - Analysis and design*, 4th Ed. Wiley, New York,1994.

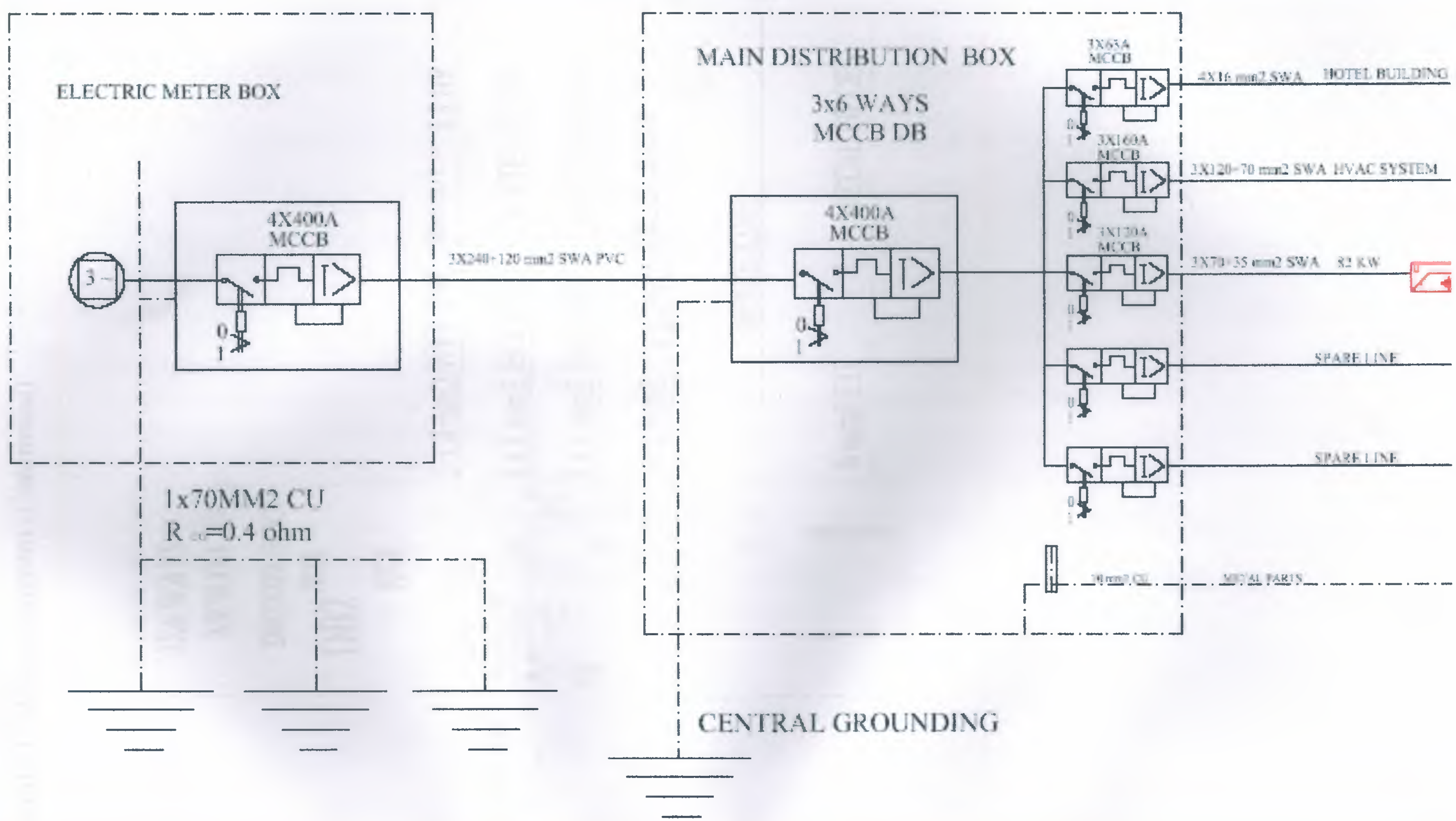
[16] Goldstick, R., Thumann, A., *Principles of waste heat recovery*, The Fairmont Press Inc., 1987

[17] *Ventilating and Air Conditioning (HVAC)*, Encarta 2004, Microsoft Corporation.

APPENDICES

Appendix 1: Wiring diagram

Appendix 2: Mechanical system


ELECTRIC METER BOX
4X400A
MCCB
3X240+120 mm2 SWA PVC
1x70MM2 CU
MAIN DISTRIBUTION BOX
3x6 WAYS
MCCB DB
4X400A
MCCB
3X63A
MCCB
4X16 mm2 SWA
HOTEL BUILDING
3X160A
MCCB
3X120+70 mm2 SWA
HVAC SYSTEM
3X120A
MCCB
3X70+35 mm2 SWA
82 KW
SPARE LINE
SPARE LINE
METAL PARTS
CENTRAL GROUNDING

Appendix 1: Wiring diagram (Continued)